

# Severe Winds

*Non-tornadic winds of 58 miles per hour or greater.*

## **Hazard Description**

Severe winds, or straight-line winds, sometimes occur during severe thunderstorms and other weather systems, and can be very damaging to communities. Often, when straight-line winds occur, the presence of the forceful winds, with velocities over 58 mph, may be confused with a tornado occurrence. Severe winds have the potential to cause loss of life from breaking and falling trees, property damage, and flying debris, but tend not to cause as many deaths as tornadoes do. However, the property damage from straight line winds can be more widespread than a tornado, usually affecting multiple counties at a time. In addition to property damage to buildings (especially less sturdy structures such as storage sheds, outbuildings, etc.), there is a risk for infrastructure damage from downed power lines due to falling limbs and trees. Large scale power failures, with hundreds of thousands of customers affected, are common during straight-line wind events.

## **Hazard Analysis**

Another dangerous aspect of straight line winds is that they occur more frequently beyond the April to September time frame than is seen with the other thunderstorm hazards. It is not rare to see severe winds ravage parts of the state in October and November—some winter storm events in Michigan have produced wind-speeds of 60 and 70 miles per hour. Stark temperature contrasts seen in colliding air masses along swift-moving cold fronts can occur during practically any month.

Figures from the National Weather Service indicate that severe winds occur more frequently in the southern-half of the Lower Peninsula than any other area of the state. On average, severe wind events can be expected 2-3 times per year in the Upper Peninsula, 3-4 times per year in the northern Lower Peninsula, and 5-7 times per year in the southern Lower Peninsula. It must be emphasized that this refers to winds from thunderstorms and other forms of severe weather, but **not** tornadoes.

Severe winds spawned by thunderstorms or other storm events have had devastating effects on Michigan, resulting in 122 deaths, nearly 700 injuries, and hundreds of millions of dollars in damage to public and private property and agricultural crops since 1970. Severe wind events are characterized by wind velocities of 58 miles per hour or greater, with gusts sometimes exceeding 74 miles per hour (hurricane velocity), but do not include tornadoes. (Please refer to the Tornadoes section which follows, for more information on that hazard.)

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National Weather Service forecasts of severe winds usually give sufficient warning time to allow residents to take appropriate action to reduce, at least to some degree, the effects of wind on structures and property. Little can be done to prevent damage from flying objects. However, proper structural bracing techniques can help minimize or even eliminate major damage due to the loss of a roof or movement of a building off its foundation.

In terms of response to a severe wind event, providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear and dispose of downed tree limbs and other debris from roadways, are the primary challenges facing Michigan communities. In addition, downed power lines present a public safety threat that requires close coordination of response efforts between local agencies and utility companies. Thunderstorms and severe winds can affect every Michigan community. Therefore, every community should adequately plan and prepare for this type of emergency. That planning and preparedness effort should include the identification of necessary resources such as cots, blankets, food supplies, generators, and debris removal equipment and services. In addition, each community should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the stream of tree and construction debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

To mitigate the effects of severe winds, communities can: 1) institute a comprehensive urban forestry program, 2) properly brace and strengthen vulnerable public facilities, 3) ensure compliance with manufactured home anchoring regulations, 4) coordinate with utility companies on local restoration priorities and procedures, 5) improve local warning systems, and 6) amend local codes to require structural bracing, where appropriate, in all new residential and commercial construction.

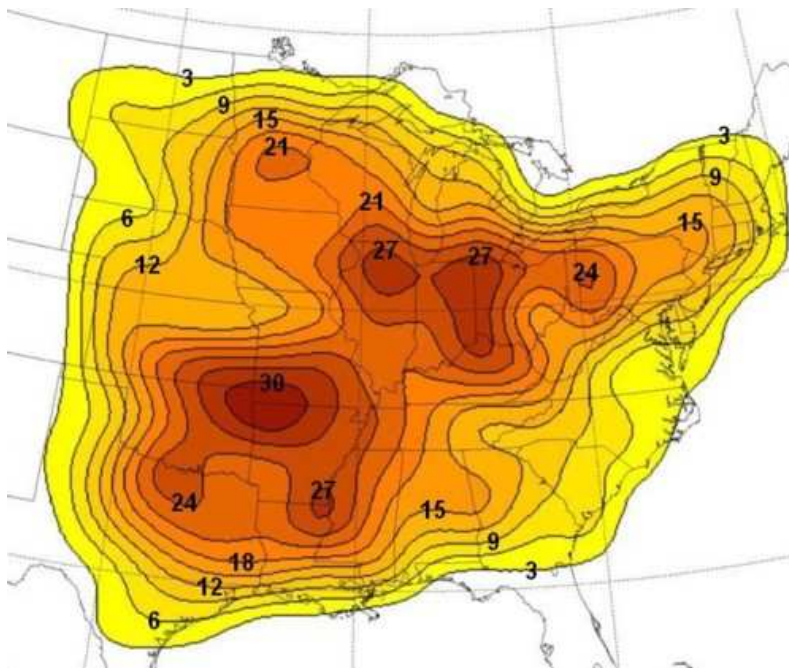
### Derecho

A Derecho, also called a bow echo, is a widespread and long-lived windstorm that is associated with a fast-moving band of severe thunderstorms. “Bow echo” describes the curved weather front that typifies a derecho, but the word “derecho” comes from the Spanish language and means “direct.” By contrast, tornado winds “turn” (the Spanish word *tornar* meaning “to turn”). The word derecho provides a conveniently brief term to describe severe non-tornadic winds. By a “widespread event” the definition means that the front can be hundreds of miles long and more than 100 miles across. The damage path of a derecho will be at least 250 miles long. Derechos are usually not associated with a cold front, but instead with a stationary front. They occur mostly in July, but can occur at any time during the spring or summer. The following map gives an indication of the pattern of Derecho frequency across the Midwest.

There are three types of Derechos:

- Serial Derecho - Multiple bow echoes embedded in a massive line typically around 250 miles long. This type of Derecho is usually associated with a very deep low pressure system. Also because of embedded supercells, tornadoes can easily spin out of these types of Derechos.
- Progressive Derecho - A small line of thunderstorms take a bow-shape and can travel for hundreds of miles.
- Hybrid Derecho - Has characteristics of a serial and progressive Derecho. These types of Derechos are associated with a deep low pressure system like serial Derechos, but are relatively small in size like progressive Derechos.

### **Moderate and High Intensity Derechos 1980-2001**



Note: Numbers on map indicate the number of Derechos that occurred during the period.  
Source: National Oceanic and Atmospheric Administration

As the following table shows, severe wind events average about 3 events per year in Upper Peninsula counties, 2 per year in northern Lower Peninsula counties, and 10 to 17 times per year in southern Lower Peninsula counties.

# Severe Wind History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013

(The Lower Peninsula regions are ordered by “tiers” from south to north, west to east)

Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	Severe Wind Events	Days with Severe Winds	Tot. property damage	Tot. crop damage	Injuries	Deaths
Washtenaw	300	151	\$13,335,000		2	1
Wayne	306	155	\$64,495,000		28	8
.Livingston	219	117	\$3,319,500		1	
Oakland	414	163	\$16,319,000		8	2
Macomb	279	133	\$22,953,000		2	
<b>5 Co Metro region</b>	<b>304 avg.</b>	<b>144 avg.</b>	<b>\$120,421,500</b>		<b>41</b>	<b>11</b>
Berrien	178	116	\$866,000	\$120,000	8	2
Cass	137	101	\$1,223,000		5	
St. Joseph	145	97	\$648,750			2
Branch	162	94	\$422,500			
Hillsdale	150	90	\$562,500		2	
Lenawee	216	113	\$7,254,000		5	
Monroe	198	124	\$5,030,000		8	
.Van Buren	114	83	\$1,511,000	\$40,000		1
Kalamazoo	124	95	\$5,808,000	\$145,000		1
Calhoun	156	110	\$29,270,000	\$235,000	10	1
Jackson	118	84	\$1,210,000	\$30,000		
.Allegan	246	153	\$2,991,000	\$125,000	3	
Barry	201	126	\$2,502,000	\$85,000		
Eaton	196	116	\$5,255,000	\$210,000		
Ingham	210	116	\$6,060,000	\$85,000		
.Ottawa	209	133	\$38,957,000	\$10,090,000	21	4
Kent	227	139	\$63,509,000	\$20,115,000	60	3
Ionia	184	116	\$2,411,000	\$75,000	2	
Clinton	196	118	\$3,077,000	\$100,000		2
Shiawassee	230	144	\$5,025,000	\$30,000		
Genesee	384	178	\$9,942,000	\$30,000	3	
Lapeer	277	162	\$5,466,000	\$30,000	1	
St. Clair	286	164	\$6,654,000	\$30,000		
.Muskegon	191	117	\$29,471,250	\$5,050,000	5	1
Montcalm	183	123	\$16,354,000	\$100,000	23	
Gratiot	162	106	\$2,478,000	\$45,000		
Saginaw	292	158	\$7,905,000	\$30,000	5	
Tuscola	145	91	\$3,290,950			
Sanilac	92	65	\$2,729,500	\$4,000	1	
.Mecosta	40	33	\$626,110	\$10,000		
Isabella	54	47	\$1,265,000	\$15,000		
Midland	88	71	\$2,828,000			
Bay	105	72	\$4,986,000			1
Huron	118	76	\$3,091,000			1
<b>34 Co S Lower Pen</b>	<b>177 avg.</b>	<b>110 avg.</b>	<b>\$280,679,560</b>	<b>\$36,829,000</b>	<b>162</b>	<b>19</b>

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**Part 2 of Michigan County Wind History Table**

.Oceana	38	32	\$4,607,000	\$50,000	37	
Newaygo	51	39	\$2,118,000	\$40,000		2
.Mason	48	39	\$1,677,000	\$15,000	5	
Lake	31	30	\$2,144,000			
Osceola	32	30	\$564,500	\$25,000	1	
Clare	41	34	\$519,500	\$15,000	1	
Gladwin	31	26	\$256,500			
Arenac	28	23	\$222,500		4	
.Manistee	45	36	\$538,500			
Wexford	36	29	\$194,000			
Missaukee	20	17	\$301,000			
Roscommon	51	40	\$233,000		1	
Ogemaw	51	41	\$450,530		1	
Iosco	36	27	\$151,000			
.Benzie	24	20	\$158,000			
Grand Traverse	38	29	\$300,500	\$1,000		
Kalkaska	28	22	\$63,000			
Crawford	28	21	\$252,000			
Oscoda	27	24	\$168,000		1	
Alcona	42	35	\$93,000		1	
.Leelanau	33	26	\$123,000	\$8,000		
Antrim	55	41	\$231,000		1	
Otsego	38	35	\$180,500			
Montmorency	38	31	\$235,000	\$5,000	1	
Alpena	40	34	\$190,000			
.Charlevoix	35	30	\$273,000			
Emmet	35	31	\$281,000		1	
Cheboygan	30	27	\$81,000	\$100,000		
Presque Isle	26	23	\$80,000			
<b>29 Co Northrn Lower Pen</b>	<b>36 avg.</b>	<b>31 avg.</b>	<b>\$16,686,030</b>	<b>\$259,000</b>	<b>55</b>	<b>2</b>
Gogebic	83	56	\$171,500	\$1,000,000		1
Iron	55	40	\$70,500	\$2,000,000		
Ontonagon	59	42	\$57,000	\$1,060,000		
Houghton	64	37	\$138,500	\$1,000,000		
Keweenaw	38	35	\$341,000			
Baraga	49	33	\$463,500			
.Marquette	119	69	\$619,750			2
Dickinson	60	42	\$878,000			
Menominee	64	46	\$124,500			
Delta	68	39	\$986,200	\$4,250,000	2	
Schoolcraft	35	31	\$675,000	\$2,613,000		
Alger	45	38	\$251,000	\$1,001,000	1	
.Luce	36	24	\$171,000	\$1,000		
Mackinac	24	21	\$89,000			
Chippewa	31	26	\$75,500			
<b>15 Co Upp.Pen</b>	<b>55 avg.</b>	<b>39 avg.</b>	<b>\$5,111,950</b>	<b>\$12,925,000</b>	<b>3</b>	<b>3</b>
<b>MICHIGAN TOTAL</b>	<b>7,324</b>	<b>780</b>	<b>\$403,452,030</b>	<b>\$49,397,000</b>	<b>261</b>	<b>34</b>

### Impact on the Public

Severe winds tend to impede transportation, causing slowed traffic and impaired control on roadways, and delays in the flight schedules for airlines. In addition, their physical impact can be comparable to that of a weak tornado, judged in terms of the severity of the resulting property damage, but with a more widespread area of effect. Structural collapse, and damages caused by falling trees/limbs, can cause injury and impairment of the residential and commercial use of the affected properties. It is very common for winds to cause trees and their limbs to break communication and power lines, causing the types of impacts described for the lightning hazard (and in the section on infrastructure failures).

### Impact on Public Confidence in State Governance

When winds cause infrastructure failures, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

### Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impacts of severe winds. Some winds, such as the most extreme gusts from severe straight-line winds (microbursts), can be brief, but can still be surprising and harmful to those caught in them. Strong winds can also persist for many hours and exacerbate the existing difficulties and challenges involved in emergency response—impeding traffic, causing power loss and road closures, and making the use of equipment more difficult.

### Impact on the Environment

Non-tornadic winds of at least 58 mph are classified as severe winds and/or derechos. Some of the harmful effects of wind on the environment include full-grown trees being completely uprooted and knocked down, or large acreage of forest land being destroyed. Large amounts of debris, elements from collapsed structures, and destroyed natural vegetation can result from severe winds. Wildlife species can be harmed. Collapsed structures can contain combustible building materials, debris, chemicals, machinery, smoke, sewage, or other elements that can damage the environment. Lakeshore beach erosion can occur, along with rip currents in the water, as a result of severe winds. Winds can stir up sediments in waterways that can also disrupt the ecosystem.

## ***Recent Significant Severe Wind Events in Michigan***

### **Various Dates – Lake Michigan (Oceana and Mason Counties)**

The twenty-mile span of Lake Michigan between Little Point Sable, at Silver Lake, and Big Point Sable, north of Ludington, has earned a reputation as the "Graveyard of Ships." Beginning with the loss of the Neptune in 1848, through the Armistice (now Veterans') Day Storm of 1940, nearly seventy vessels have gone down in these treacherous waters. Gales and November snow storms have made navigation of this part of the lake a sailor's nightmare. Significant among the losses near Pentwater Harbor were the schooner Wright in 1854, the Minnie Corlett and the Souvenir in 1875, the Lamont in 1879 and the tug Two Brothers in 1912. The freighters William B. Davock, Anna C. Minch and Novadoc were all lost on November 11, 1940.

### **November 18, 1958 – Lake Michigan**

The November 18, 1958 sinking of the 615-foot Carl D. Bradley limestone carrier in Lake Michigan, 60 miles west of the Mackinac Bridge, was due to excessive waves caused by winds up to 100 miles per hour. Mariners theorized that the "working" of the steel hull by 20-foot waves popped the rivets that held the ship's plates together, causing the large vessel to split in two and sink. Thirty-three of the 35 crewmen onboard died in the accident.

### **November 10, 1975 – Lake Superior**

The November 10, 1975 sinking of the freighter Edmund Fitzgerald in Lake Superior was due to excessive waves caused by severe winds exceeding 60 miles per hour. A total of 29 crewmen died in the accident.

### **July 15-20, 1980 – Southern Lower Michigan**

Wind-related damages were so severe in the southern Lower Peninsula from July 15-20, 1980 that a Presidential Major Disaster Declaration was granted for 10 counties. Over 300,000 electrical customers were left without power, some for several days. During the recovery process, almost \$6.8 million in public and private assistance was made available to affected local jurisdictions and to residents in the affected areas. Four million dollars in low-interest disaster loans were made available through the Small Business Administration.

### **April 30, 1984 – Lower Michigan**

On April 30, 1984 a windstorm struck the entire Lower Peninsula, resulting in widely scattered damage, 1 death, and several injuries. Wind gusts measured up to 91 miles per hour in some areas. Damage was widely scattered, but extensive, with 6,500 buildings, 300 mobile homes, and 5,000 vehicles being damaged. Over 500,000 electrical customers lost power. In addition, 10-16 foot waves on Lake Michigan caused severe shore erosion, collapsing some cottages and driving many boats aground.

## **March 27, 1991 – Central and Southern Lower Michigan**

On March 27, 1991 severe thunderstorms and accompanying high winds caused considerable damage across a large portion of central and southern Lower Michigan, damaging homes, businesses, farms, and some public facilities. A total of three deaths and 27 injuries were attributed to the storms, and power was lost to 450,000 electrical customers (many for up to one week). The storms also spawned tornadoes and hail in some areas. Damage to homes and businesses was estimated at over \$30 million, with almost all of those losses covered by private insurance.

## **July 7, 1991 – Southern Lower Michigan**

On July 7, 1991 a line of severe thunderstorms with very high winds crossed the southern Lower Peninsula. The National Weather Service recorded wind speeds of 60-70 miles per hour, with gusts in several locations exceeding 80 miles per hour. Several million dollars in damage occurred, and over one million electrical customers (more than 10% of the State's population) were left without power, some for several days. In addition, thousands of downed power lines caused significant public safety concerns and burdened an already difficult restoration process.

## **July 13-15, 1995 – Statewide**

From July 13-15, 1995 severe thunderstorms damaged numerous areas of Michigan. These storms, which produced winds up to 100 miles per hour with damaging golf ball-sized hail and severe lightning, damaged hundreds of structures and downed thousands of trees and power lines statewide. Damage was widespread, but the impacts were not severe or extensive enough in any one location to require supplemental disaster assistance. The strong winds produced widespread power outages. More than 400,000 electrical customers in southeast Michigan lost power due to the storms. In Roscommon County, over 100,000 trees were toppled by the winds. Wind gusts in that area were estimated in the 85-100 miles per hour range. One person was killed when her pontoon boat flipped over while attempting to return to its dock. One person was killed in Huron County when a barn collapsed between Bad Axe and Harbor Beach.

## **April 6-7, 1997 – West Michigan**

On April 6-7, 1997, an intense early spring low pressure system moving across the Great Lakes brought gale force winds to much of Lower Michigan. Wind gusts of 50-70 miles per hour created 10-15 foot waves on the Lake Michigan shoreline, causing widespread wind damage and lakeshore beach erosion. Private damage was estimated at \$5 million, most of that occurring in a handful of West Michigan counties. The winds downed numerous trees and power lines across the region, causing roof damage to many structures and power outages for nearly 200,000 Consumers Energy electrical customers. The U.S. Army Corps of Engineers estimated that the severe beach erosion resulted in as much as 20 feet of beach loss in some areas. The beach erosion was due in part to the unusually high Great Lakes water levels, nearly 38 inches above average. One injury was later reported in this severe wind event.

## **July 2, 1997 – South-Central and Southeast Michigan**

On July 2, 1997 a series of intense thunderstorms went through south-central and southeast Michigan, spawning severe straight-line winds, several tornadoes, and heavy rainfall. In some areas, the straight-line winds reached speeds of 70-100 miles per hour, causing significant structural damage and massive amounts of debris. The severe storms and the associated impacts caused a total of 16 deaths and 120 injuries. The tornadoes and straight-line winds downed thousands of trees and power lines, which knocked out power to 350,000 electrical customers. A Presidential Major Disaster Declaration was granted for the five county area most severely impacted by the storm event. (See the Tornadoes section for additional details on the tornadoes associated with these severe thunderstorms.)

## **October 5, 1997 – Delta and Schoolcraft Counties**

Severe thunderstorms out of Canada pushed their way through the Upper Peninsula on October 5, 1997, creating numerous microbursts (small, powerful downdrafts) that caused significant damage in Delta and Schoolcraft counties. Winds estimated in excess of 100 miles per hour cut a 12-mile wide swath of destruction in the two counties, downing thousands of trees and damaging 600 buildings and numerous vehicles. Total property, tree and agricultural losses were estimated at \$3 million. The U.S. Forest Service reported damage to 9,000 acres of forest. The Michigan Department of Natural Resources suffered 500 acres of tree loss, and 200 acres of corporate forest were also heavily damaged. Fortunately, these microbursts occurred in lightly populated areas, or the threat to life and property might have been much greater.

## **May 31, 1998 – Southern Lower Peninsula**

On May 31, 1998 a derecho raced across the Lower Peninsula around 4:30am, producing widespread 60 to 90 mph wind gusts that caused extensive tree and structural damage and left over 861,000 homes and businesses without electricity. Consumers Energy reported the derecho as the most destructive weather event in its history, leaving over 600,000 of its customers without power. There were four storm-related fatalities and 146 injuries (mostly minor) reported in the state. Statewide, approximately 250 homes and 34 businesses were destroyed and 12,250 homes and 829 businesses were damaged. Damage estimates totaled over \$166 million. The highest wind gusts reached 120 to 130 mph in Spring Lake (Ottawa County) and Walker (Kent County), 100 mph in portions of Montcalm County (including Cody Lake and Stanton), and 90 mph in Rockford (Kent County) and Zeeland (Ottawa County). It took up to 10 days to fully restore power to certain areas, including the City of Walker and portions of Montcalm and Gratiot Counties. A Presidential Disaster Declaration was declared for 13 counties.

## **September 26-27, 1998 – Northern Lower Michigan**

During the weekend of September 26-27, 1998, severe thunderstorms ravaged northern Lower Michigan, producing strong winds that damaged or destroyed homes, businesses and public facilities, and downed trees and power lines. Otsego County, specifically the city of Gaylord, was hardest hit, although damage was also reported in Crawford and Charlevoix counties as well. The storm front, which ran along and north of the M-32 corridor from East Jordan to Alpena, was approximately 12 miles wide and 15 miles long. When the front slammed into Gaylord, wind speeds had reached hurricane force of 80-100 miles per hour. The wind was accompanied by brief heavy rainfall and golf ball sized hail. The storm lasted only a few minutes in Gaylord, but the damage was tremendous. Thousands of trees were snapped off at waist level, homes and businesses were torn apart, power lines were downed, and several public facilities were substantially damaged – including the Otsego County Courthouse, which lost half of its roof. Approximately 818 homes were damaged throughout Otsego County, including 47 that were destroyed and 92 that incurred major damage. In addition, the storm injured 11 persons – none seriously. Region-wide, about 12,000 electrical customers lost power. A Governor's Disaster Declaration was granted to the county, to provide state assistance in the debris cleanup effort.

## **November 10-11, 1998 – Statewide**

One of the strongest storms ever recorded in the Great Lakes moved across Michigan on the 10th and 11th of November, 1998, producing strong, persistent winds that damaged buildings, downed trees and power lines, killed one person, and left over 500,000 electrical customers in the Lower Peninsula without power. Wind gusts of 50-80 miles per hour were common, and a peak gust of 95 miles per hour was reported on Mackinac Island. Damage was widespread but relatively minor for a storm of that intensity. However, there were several pockets of significant damage across the state. In Troy, the walls of a church under construction were destroyed. In Flint, a warehouse lost its roof to the wind, and another had its roof damaged. In Mt. Clemens, a boat storage rack collapsed, causing about \$500,000 in damage to 20 boats. In Frankfort, on the Lake Michigan shoreline, 80-90 mile per hour wind gusts destroyed a hangar at the City-County Airport (\$500,000 in damage) and damaged six private planes. In Lake City, the roof was blown off a hardware store. The U.S. Forest Service reported that at least \$10 million worth of timber was lost in the Ottawa and Hiawatha National Forests. The strong winds generated 15-20 foot waves on Lake Michigan, while 8-15 foot waves were reported along the western Lake Superior shoreline. The waves caused considerable beach erosion in both locations.

The extended period of strong winds even affected the water level in Saginaw Bay. By the morning of November 11, the winds had pushed so much water out into Lake Huron that the water level on Saginaw Bay bottomed out 50" below chart datum – over 5 feet below the recent average. The temporary loss of over 5 feet of water in the shallow bay exposed up to one-half of the bay bed, which briefly became dry land during the storm. As the wind died down later in the day, the water level rose again to its more normal level. Coincidentally, this storm system occurred on the anniversary of the storm system that had sunk the freighter Edmund Fitzgerald in Lake Superior in 1975.

## **May 17, 1999 – Central and Southern Lower Michigan**

On May 17, 1999 a strong storm system raced through central and southern Lower Michigan, bringing with it severe winds, heavy rain, and large hail. Wind gusts of 60-70 miles per hour downed numerous trees and power lines, leaving 150,000 homes and businesses without power. Peak wind gusts of 115 miles per hour were recorded near Wyoming, Lansing, and Battle Creek. A wind gust caused a home under construction to collapse in Wyoming, killing one person and injuring another. In Lansing, utility poles along I-496, built to withstand 100 mile per hour winds, were snapped off like twigs, closing parts of the freeway for 26 hours and causing rush hour traffic tie-ups. Response and recovery costs for Lansing city agencies (including the municipal power company) were pegged at \$1.5 million.

## **July 4-5, 1999 – Several Northern States**

The Boundary Waters-Canadian Derecho, also commonly called the Boundary Waters Blowdown, was an international Derecho that occurred during the afternoon and evening hours of July 4 and the early morning hours of July 5, 1999. It was classified as a progressive Derecho and it traveled over 1300 miles in 22 hours through Minnesota, Wisconsin, Michigan, Ontario, Quebec and Maine. There was also a tremendous amount of lightning associated with this Derecho, around 6,000 lightning strikes per hour. This event was one of the northernmost progressive Derechos to have ever been recorded. It caused \$100 million in damage, killed 2 people and injured 70. Over 700,000 homes and businesses lost power from the event.

## **July 24-25 and 31, 1999 – Southern Lower Michigan**

During the last two weekends of July 1999, a series of severe thunderstorms, fueled by high temperatures and extreme humidity, moved across southern Lower Michigan. The storms produced strong wind gusts (estimated at 60-70 miles per hour), heavy rainfall, and hail in some areas. Most of the damage caused by the wind involved downed trees and power lines. A total of 430,000 electrical customers were left without power after the two weekend storms, many for more than 24 hours. Unfortunately, the outages occurred at a time when temperatures were soaring past 90 degrees and humidity was unbearably high. Many electrical customers lost large amounts of perishable food to spoilage. Restoration efforts after the July 24 storms were further complicated when another series of storms struck on the 25<sup>th</sup>, forcing utility crews to temporarily halt their restoration efforts. Damage to homes, businesses, vehicles, and boats was reported in southeast Michigan and the Saginaw Bay area. In Detroit, heavy rainfall flooded freeway underpasses with up to two feet of water, while golf ball sized hail was reported in Kawkawlin, Bay City, Zilwaukee, Goodrich, and Southfield.

## **May 9, 2000 – Southeast Michigan**

During the afternoon and evening hours of May 9, 2000, an outbreak of severe thunderstorms (with winds gusting to 70 miles per hour) struck southeast Michigan, causing considerable damage across the region. The storm front produced a combination of straight-line winds and some reported tornadoes, accompanied by large, damaging hail in many locations. In Lenawee County, strong winds destroyed several barns, flipped over a mobile home and recreational vehicle, caused numerous trees to fall on homes, destroyed grain bins, and destroyed one airport hangar and damaged two others. In Monroe County, dozens of trees were downed and a railroad depot was destroyed. In Washtenaw County, hundreds of trees were downed and a church and a grocery store were damaged. In Wayne County, a hangar at Detroit Metropolitan Airport collapsed, damaging the plane inside. Numerous other localities within Wayne County suffered damage to homes and businesses. All totaled, the storms left more than 200,000 electrical customers without power, injured at least six persons, and caused several million dollars in property damage.

## **October 24, 2001 – Southern Lower Michigan**

On October 24, 2001, much of Michigan began experiencing severe weather as the result of a strong cold front colliding with warm, moist air. The result was widespread strong winds (in excess of 50 miles per hour) and severe weather throughout the state, but particularly so in southern Lower Michigan where severe thunderstorm warnings were issued for 13 counties, and tornado warnings were issued for seven counties. Although numerous funnel clouds were sighted across the region, only two actually touched down – one affecting Livingston and Oakland Counties along a 15-mile path, and the other affecting Saginaw County. The vast majority of the damage produced by this storm system was from straight-line winds, the strongest of which were reported in Lansing and estimated at 120 miles per hour.

Region-wide, the storms killed two persons and injured at least 20 others, caused extensive flooding of roads and streets, downed thousands of trees and power lines (leaving 195,000 electrical customers without power), closed schools and businesses, and damaged hundreds of cars, homes and businesses, and public buildings. The areas most heavily impacted by this storm system included the counties of Berrien, Cass, and Kalamazoo, and the cities of Lansing and East Lansing. A Governor's Disaster Declaration was issued for Kalamazoo County to provide supplemental state assistance for debris removal and cleanup.

## **July 31-August 2, 2002 – Central Michigan and Upper Peninsula**

During the last day in July, severe weather hit central Michigan and the Upper Peninsula. The National Weather Service issued tornado warnings for seven counties in central Michigan. Funnel clouds were reported along a 120-mile stretch extending from Howard City to Onaway. Golf ball-size hail fell in Escanaba and thunderstorms soaked Houghton with 1.25" of rain in a two-hour period. About 14,000 Upper Peninsula Power Company customers lost electricity for several days due to 70 mile per hour winds that toppled trees and power lines in the western Upper Peninsula. Some Houghton customers were blacked out when high winds tore the metal roof off a Frito-Lay warehouse and it sliced through nearby power lines. From Tuesday night through midday Thursday, the National Weather Service issued 44 severe weather warnings for various parts of the Upper Peninsula.

## **May 11, 2003 – Southeast Michigan**

A strong cold front moved through the Great Lakes region during the morning of the May 11, 2003. Wind gusts of 55 to 60 mph were estimated across much of Wayne and Washtenaw counties. The rest of Southeastern Michigan generally had estimated wind gusts of 45 to 50 mph. The winds caused several trees to blow down across the area and several thousand homes and businesses across the area to lose power. The strong winds were also blamed for a hydrochloric acid leak from a plant in Ypsilanti. Investigators concluded that the high winds ripped a chunk of the plant's roof loose, smashing it into a distribution pipe, which caused roughly 100 gallons of acid to leak out.

## **July 4-6, 2003 – Southern Lower Michigan**

A line of thunderstorms that developed over Wisconsin made its way across Lake Michigan over the Independence Day weekend, bringing wind gusts of more than 60 miles per hour, knocking down trees and leaving more than 200,000 customers without electricity. Power went out during one of the warmest weeks of the summer, causing many citizens to lose large amounts of perishable foods. In Brighton Township, residents of a subdivision were without running water for several days because they relied on electricity to operate wells. A small stretch of beaches in southwest Michigan turned deadly over the weekend, as 10 swimmers drowned from the storm-powered undercurrents. On July 4, more swimmers drowned in one day than drown all summer, on average, in southwest Michigan. Nine fatal car accidents also occurred over the holiday weekend due to the severe weather.

## **August 1, 2003 – Southern Lower Michigan**

Severe thunderstorms and winds up to 77 miles per hour swept through southern Lower Michigan on August 1, 2003, killing two persons. One man was killed while he was walking when high winds snapped off a tree limb, hitting him on the head. A woman was pronounced dead at a local hospital after being struck by lightning. A young boy survived a lightning strike the same day. The high winds caused about 127,000 electrical customers to lose power - most of whom had it restored within a couple of days.

## **November 11, 2003 – Southeast Lower Michigan**

Wind gusts up to 74 miles per hour knocked down trees and power lines, causing a loss of power for more than 370,000 electrical customers in southeast Michigan. The harsh weather conditions forced many school districts to cancel classes. A live power line fell across eastbound Interstate 94 near Monroe, forcing the closure

of the highway and causing a major traffic jam near Detroit Metropolitan Airport. Detroit's Department of Public Works received 73 telephone calls reporting trees down and other damage.

#### **November 6, 2005 – Southeast Michigan**

On November 6, 2005 a deep and rapidly intensifying storm system moved through Southeast Lower Michigan during the morning. High winds along the associated cold front knocked down trees, leading to approximately 200,000 power outages. Winds were sustained out of the southwest at 30 to 40 mph, with gusts as high as 60 mph from mid to late morning. Street signs were toppled, traffic lights were sent spinning, and power lines were split. Many streets and roads had to be temporarily closed until trees blocking the way could be cleared. Property damage was estimated at \$4.2 million.

#### **May 15, 2007 – Southern Lower Michigan**

Severe thunderstorm winds affected many counties and measured as high as 83 knots (at the Three Rivers Airport in St. Joseph County). Significant damages were caused at locations as diverse as Centreville, Schoolcraft, North Aurelius, and Howell. One mile north of Essexville (Bay County), a power plant's coal stacker was reported as having been destroyed when it was toppled over by strong winds, with damages estimated at \$1.5 million.

#### **June 6, 2008 – Southern Lower Michigan**

Numerous thunderstorms produced damaging winds of up to 65 knots. The strongest winds were reported at Howell and Saginaw. The greatest damages occurred in the Saginaw area, where 12,000 residents lost electricity. Two miles north of Carrollton, dozens of trees were blown down, some knocking down power lines, some falling onto houses, some blocking roads, and one falling onto a car and injuring its two occupants. An entire roof was blown off a commercial building near the intersection of Stevens and Hamilton.

#### **June 8, 2008 – Southern Lower Michigan**

A derecho swept across many counties in the southern Lower Peninsula, involving winds as high as 74 knots (at Marine City). There were also tornadoes associated with this system. Along with an estimated \$100 million in total damages, several casualties were caused by the storm systems, and more than 10,000 persons were without power for a week or more. This was the worst such wind event of the decade. Thousands of trees were lost, and great property damage was caused as they toppled onto houses and cars. One mile west of Spring Lake, a car was struck by a tree while it was being driven, killing the driver and injuring the passenger. A pedestrian was also killed by a falling tree, a mile southeast of Harrisburg. Numerous power lines were down, and boats were overturned in the water.

#### **August 9, 2009 – Ottawa and Kent Counties**

On August 9, 2009 severe thunderstorms developed across Ottawa and Kent Counties, resulting in hundreds of trees being blown down and numerous utility poles and wires taken down by 60 to 80 mph winds. Fruitport took the brunt of the storm, with wind gusts of 70 to 80 mph lasting for about 10 minutes. Numerous homes were heavily damaged by falling trees. Significant damage to apple orchards occurred west of Sparta. The storm complex also produced an EF-0 tornado path 35 miles long, and up to 9 miles wide.

#### **July 18, 2010 – Kent County**

On July 18, 2010 a NWS storm survey team concluded that a series of wet micro bursts across southwestern Kent County had produced wind gusts ranging from 60 up to 80 mph, brought down several trees and power lines in the Wyoming and Cutlerville areas, and flipped over and destroyed 8 wood and metal sheds at a store near Cutlerville. A tornado damaged a home and broke or uprooted several trees just northeast of Wayland. A roof was lifted off of a garage in Wyoming, a shed was destroyed, and some structural damage occurred to one home, due to wind gusts estimated to be as much as 80 mph.

#### **May 29, 2011 – Mid-Michigan (Calhoun, Kalamazoo, Eaton, and Ingham Counties)**

Severe thunderstorms resulted in straight-line winds of up to 85 to 100 mph, causing extensive damage across multiple counties. A state of emergency was declared for Calhoun County due to widespread wind damage. Nearly 40,000 people across Calhoun County had lost power due to wind and lightning damage. While no lives were lost, over 600 properties were damaged and 76 homes and 4 businesses in the Battle Creek area were destroyed. The total damage estimates were over \$29M, approximately \$25M of which was in Calhoun County.

#### **July 11, 2011 – Western Michigan (Kent, Ottawa, and Kalamazoo Counties)**

Two separate bow echoes moved across the western Lower Peninsula on July 11, producing numerous reports of wind damage. The first bow echo moved onshore north of Muskegon shortly after daybreak. The second, more destructive bow echo raced east from northern Illinois across far southern Lake Michigan and southern lower Michigan, resulting in numerous reports of downed trees and power lines. One person lost his life in Cutlerville when a tree fell in the garage he was in. Wind gusts up to 80mph were reported and the storm resulted in approximately \$8M damage—mostly in Kent County (\$5M) but also in Ottawa (\$2M) and Kalamazoo County (\$1M).

#### **January 19th, 2013 – Southeast Michigan**

An intense Arctic Front swept through southeast Michigan around Midnight of January 19th, with westerly winds gusting as high as 60 mph across much of the area during the early morning hours of January 20th. Trees and power lines were downed across individual counties, leading to power outages in excess of 120,000 DTE customers during the peak of the winds. The storm resulted in more than \$7.5M damage across 7 counties, including \$2M in Wayne County, \$1.5M each in Oakland and Macomb Counties, and \$1M each in Tuscola, Huron, Genesee, and St. Clair.

### ***Programs and Initiatives***

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from tornado effects have the dual purpose of also protecting against severe straight-line winds. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

#### **National Weather Service Doppler Radar**

The National Weather Service (NWS) has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including severe winds. Most important, the lead time and specificity of warnings for severe weather have improved significantly.

Doppler technology calculates both the speed and the direction of motion of severe storms. By providing data on the wind patterns within developing storms, the new system allows forecasters to better identify the conditions leading to severe weather such as tornadoes and severe straight-line winds. This allows early detection of the precursors to severe storms, as well as information on the direction and speed of storms once they form.

### National Weather Service Watches/Warnings

The National Weather Service issues severe thunderstorm watches for areas where the meteorological conditions are conducive to the development of severe thunderstorms. People in the watch area are instructed to stay tuned to National Oceanic and Atmospheric Administration (NOAA) weather radio and local radio or television stations for weather updates, and watch for developing storms. Once radar or a trained Skywarn spotter detects the existence of a severe thunderstorm, the National Weather Service will issue a severe thunderstorm warning. The warning will identify where the storm is located, the direction in which it is moving, and the time frame during which the storm is expected to be in the area. Persons in the warning area are instructed to seek shelter immediately.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), NOAA weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet at [www.weather.gov](http://www.weather.gov), where an interactive map can be used.

### Public Warning Systems

Numerous communities in Michigan have outdoor warning siren systems in place to warn the public about impending tornadoes and other hazards. Most of these systems were originally purchased to warn residents of a nuclear attack, but that purpose was expanded to include severe weather hazards as well. These systems can be very effective at saving lives in densely populated areas where the siren warning tone is most audible. In more sparsely populated areas where warning sirens are not as effective, communities are turning to NOAA weather alert warning systems to supplement or supplant outdoor warning siren systems. Unfortunately, a large number of communities across the state do not have adequate public warning systems in place to warn their residents of severe weather or other hazards. Federal funding specifically allocated to assist communities in the purchase of public warning systems has effectively disappeared, leaving many communities unable to purchase adequate systems to warn their residents of impending danger.

Attempting to fill some of that funding void, the State of Michigan has used federal Hazard Mitigation Grant Program (HMGP) funds to assist local communities in purchasing public warning systems. To date, HMGP funds have been used to purchase and install more than 80 outdoor warning sirens, over 1,000 NOAA weather alert monitors for schools, hospitals and places of public assembly, four NOAA weather radio transmitters, and several other early warning systems. Communities that received funding for these projects were encouraged to implement a warning education program to ensure that residents know what to do once they receive warning of an impending hazardous event. Because HMGP funds must be used to fund a wide variety of mitigation projects, the amount of funds available to fund warning systems is limited to a small percentage of the overall available grant funds allocated to the state. The HMGP funds are provided on a 75% federal, 25% local cost share. A Presidential major disaster declaration is required to activate the HMGP funding. As a result, the funding stream may not always be available in the future. In addition, state mitigation priorities may change over time, putting public warning systems at a lower priority than other mitigation projects. However, the HMGP does provide at least one possible avenue for assisting communities in enhancing their local public warning capability.

### Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week. This annual public information and education campaign focuses on severe weather events such as tornadoes, thunderstorms, lightning, hail, flooding and high winds. Informational materials on severe winds and other weather hazards are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

### Manufactured Home Anchoring

Manufactured homes are vulnerable to wind damage if they are not properly anchored down. As a result, a major national effort has been initiated to encourage the structural anchoring or “tie down” of manufactured homes. The Michigan Manufactured Housing Commission Administrative Rules (R 125.1602, Subsection 5) require new manufactured home installations in floodplains to be structurally anchored to a foundation. Through this requirement,

the possibility of damage from wind is minimized. Unfortunately, structures outside designated floodplains do not have to comply with the anchoring provision, although many owners choose to comply voluntarily. It should also be noted that local communities have the option of adopting an ordinance that requires anchoring of manufactured home installations located outside a designated floodplain. State anchoring system standards are outlined in Administrative Rules R 125.1605 through R 125.1608.

#### Electrical Infrastructure Reliability

One of the major problems associated with severe winds is the loss of electric power. As mentioned previously, Michigan has had numerous widespread and severe electrical power outages caused by severe winds, and several of those outages have resulted in upwards of 500,000 electrical customers (more than 5% of the State's population) being without power for several hours to several days at a time. Wind-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. Detroit Edison, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by severe winds and other hazards. Typically, these programs focus on trimming trees to prevent the encroachment of overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new distribution lines underground. The Michigan Public Service Commission (MPSC) monitors power system reliability to help minimize the scope and duration of power outages.

#### Structural Bracing and Wind Engineering

One of the best ways to protect buildings from severe wind damage is to install structural bracing and metal connectors (commonly called hurricane clips) at critical connecting points in the frame of the structure. Typically, this involves adding extra gable end bracing at each end of the structure, anchoring the roof rafters to the walls with metal connector straps, and properly anchoring the walls and sill plate to the foundation. This extra bracing helps ensure that the roof stays on the structure, and the structure stays anchored on its foundation. Experience in high wind events has shown that once the roof begins to peel away from the walls, or the building begins to move off its foundation due to extreme lateral wind forces, major structural damage occurs. If the damage continues unabated, the building can end up being a total loss.

#### Urban Forestry and Tree Maintenance Programs

Urban forestry programs can be very effective in minimizing storm damage caused by falling trees or tree branches. In almost every severe wind event, falling trees and branches cause power outages and clog public roadways with debris. However, a properly designed, managed and implemented urban forestry program can help keep tree-related damage and impact to a minimum. To be most effective, an urban forestry program should address tree maintenance in a comprehensive manner, from proper tree selection, to proper placement, to proper tree trimming and long-term care.

Every power company in Michigan has a tree trimming program, and numerous local communities have some type of tree maintenance program. The electrical utility tree trimming programs are aimed at preventing encroachment of trees and tree limbs within power line rights-of-way. Typically, professional tree management companies and utility work crews perform the trimming operations. At the local government level, only a handful of Michigan communities have actual urban forestry departments or agencies. Rather, crews from the public works agency or county road commission perform the bulk of the tree trimming work.

When proper pruning methods are employed, and when the work is done on a regular basis with the aim of reducing potential storm-related damage, these programs can be quite effective. Often, however, tree trimming work is deferred when budgets get tight or other work is deemed a higher priority. When that occurs, the problem usually manifests itself in greater storm-related tree debris management problems down the line.

#### ***Mitigation Alternatives for Severe Winds***

- Increased coverage and use of NOAA Weather Radio.
- Public early warning systems and networks.
- Tree trimming and maintenance to prevent limb breakage and safeguard nearby utility lines. (Ideal: Establishment of a community forestry program with a main goal of creating and maintaining a disaster-resistant landscape in public rights-of-way.)
- Buried/protected power and utility lines. (NOTE: Where appropriate. Burial may cause additional problems and costs in case of breakage, due to the increased difficulty in locating and repairing the problem.)

- Using appropriate wind engineering measures and construction techniques (e.g. structural bracing, straps and clips, anchor bolts, laminated or impact-resistant glass, reinforced entry and garage doors, window shutters, waterproof adhesive sealing strips, and interlocking roof shingles) to strengthen public and private structures against severe wind damage.
- Proper anchoring of manufactured homes and exterior structures such as carports and porches.
- Construction of concrete safe rooms in homes and shelter areas in mobile home parks, fairgrounds, shopping malls, or other vulnerable public areas.

#### ***Tie-in with Local Hazard Mitigation Planning***

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of severe winds), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, the information immediately following provides advice regarding the severe wind hazard to offer guidance to local planners, officials, and emergency managers. It has been adapted from the February 2003 “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207). For the second type of State-local planning coordination, a section follows that summarizes severe wind information as it has been reported in local hazard mitigation plans. For a brief summary of wind-related information from that section of this plan, it will here be noted that severe winds were identified as one of the most significant hazards in local hazard mitigation plans for the following counties: Alger, Allegan, Antrim, Arenac, Benzie, Berrien, Branch, Calhoun, Cass, Charlevoix, Clare, Crawford, Delta, Dickinson, Eaton, Emmet, Genesee, Grand Traverse, Gratiot, Huron, Ingham, Isabella, Kalkaska, Kent, Keweenaw, Lake, Lapeer, Leelanau, Lenawee, Livingston, Mackinac, Macomb, Mason, Midland, Missaukee, Monroe, Muskegon, Newaygo, Oakland, Oceana, Ogemaw, Oscoda, Ottawa, Presque Isle, Roscommon, Saginaw, Shiawassee, Tuscola, Van Buren, Washtenaw, Wayne, Wexford (52 counties).

# Tornadoes

*An intense rotating column of wind that extends from the base of a severe thunderstorm to the ground.*

## ***Hazard Description***

Tornadoes are rapidly rotating columns of air that form most often in some severe thunderstorms during Michigan's warm months. Tornadoes are high-profile hazards that can cause catastrophic damage to either a limited or an extensive area. A tornado can have winds in excess of 300 miles per hour and can have widths over one mile. The deaths and injuries associated with tornadoes have declined since the 1950s, thanks to advances in severe weather forecasting and technology improvements, but tornadoes can still be deadly killers. Although tornado deaths have decreased, tornado damages have increased in recent years, since a larger part of the country's land area contains developments with each passing year.

There can be wide sections of a community completely destroyed by one or more tornadoes. Neighborhoods can be reduced to piles of splintered trees and homes, and a junkyard of twisted metal objects. A strong tornado can level everything in its path. Communities need to be prepared for the possibility of having many residents without homes, areas with no power or phone lines, a series of burst pipes, and a gigantic amount of wooden and metallic debris to clean up (in patterns that are both scattered and concentrated).

It should be kept in mind that winds are invisible until they pick up a sufficient amount of material that can allow their patterns to be seen, and it is this carried material that provides a tornado with a visible form that is easy to recognize. Funnel clouds can be invisible except for the liquid, dust, and debris that they carry. Therefore, a tornado can be present but not yet discernable to nearby persons. This is one reason why tornado warnings need to be taken seriously. A tornado's initial presence might only be directly observed by its effects upon things at ground level, with the main funnel cloud visibly forming only after enough material has been swept up from the ground. Many persons have placed themselves at risk by not realizing that tornadoes do not always appear in their classic, fully visible form. That classic darkly visible form is merely the one that is most easily discernable in photographs, and is therefore the form that is most widely recognized from such photographs and video. Moreover, tornadoes often reach beyond existing visible funnels (and multiple tornadoes can form simultaneously).

## ***Hazard Analysis***

Tornadoes in Michigan are most frequent in the spring and early summer when warm, moist air from the Gulf of Mexico collides with cold air from the polar regions to generate severe thunderstorms. These thunderstorms often produce the violently rotating columns of wind known as funnel clouds. Winds that converge from different directions, heights, or at different speeds are the source of the spinning pattern that gets concentrated as distinct funnels of wind. Michigan lies at the northeastern edge of the nation's primary tornado belt, which extends from Texas and Oklahoma through Missouri, Illinois, Indiana, and Ohio. Most of a tornado's destructive force is exerted by the powerful winds that knock down walls and lift roofs from buildings in the storm's path. The violently rotating winds then carry debris aloft that can be blown through the air as dangerous missiles, which provides the other mechanism by which tornadoes can cause such severe destruction.

A tornado may have winds of over 200 miles per hour, and this is the source of their destructive power. Although a tornado may have an interior air pressure that is 10-20% below that of the surrounding atmosphere, the effect of this difference is insignificant compared with the force directly applied by the winds. (The old belief that opening windows to equalize air pressure was a misguided and harmful one—closer analysis of filmed images and damage patterns has since revealed that it is the force of winds that lift eaves and break down walls which causes some structures to appear to implode or explode under a direct tornado strike.) The typical length of a tornado path is approximately 16 miles, but tracks much longer than that – even up to 200 miles – have been reported. Tornado path widths are generally less than one-quarter mile wide. Typically, tornadoes last only a few minutes on the ground, but those few minutes can result in tremendous damage and devastation. Historically, tornadoes have

resulted in tremendous loss of life, with the mean national annual death toll being 87 persons. Property damage from tornadoes is in the hundreds of millions of dollars every year.

Tornado intensity is measured on the Enhanced Fujita Scale, which examines the damage caused by a tornado on homes, commercial buildings, and other man-made structures. The Enhanced Fujita Scale rates the intensity of a tornado based on damaged caused, not by its size. It is important to remember that the size of a tornado is not necessarily an indication of its intensity. Large tornadoes can be weak, and small tornadoes can be extremely strong, and vice versa. It is very difficult to judge the intensity and power of a tornado while it is occurring. Generally, that can only be done after the tornado has passed, using the Enhanced Fujita Scale as the measuring stick. The Enhanced Fujita Scale is presented in the following table.

Although tornadoes are most commonly reported between 3pm and 9pm, they can occur at any time. Although they generally exist at the trailing edge of a thunderstorm, it is possible for them to be present in other locations and less readily recognized weather patterns.

### **The Enhanced Fujita Scale of Tornado Intensity**

<b>EF-Scale Number</b>	<b>Intensity Descriptor</b>	<b>Wind Speed (mph)</b>	<b>Type/Intensity of Damage</b>
EF0	Gale tornado	65-85	Light damage. Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
EF1	Weak tornado	86-110	Moderate damage. The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
EF2	Strong tornado	111-135	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	Severe tornado	136-165	Severe damage. Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
EF4	Devastating tornado	166-200	Devastating damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
EF5	Incredible tornado	Over 200	Incredible damage. Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged; incredible phenomena will occur.

NOTE: When describing tornadoes, meteorologists often classify the storms as follows:  
EF0 and EF1 = weak tornado; EF2 and EF3 = strong tornado; EF4 and EF5 = violent tornado

(Source: The Tornado Project; Storm Data, National Climatic Data Center)

According to the National Weather Service (NWS), since 1950 the vast majority of tornadoes that occurred in the United States (approximately 74%) were classified as weak tornadoes (EF0 or EF1 intensity). Approximately 24% were classified as strong tornadoes (EF2 or EF3 intensity), and only 3% were classified as violent tornadoes (EF4 or EF5 intensity). Unfortunately, those violent tornadoes, while few in number, caused about 65% of all tornado-related deaths nationally. Strong tornadoes accounted for another 33% of tornado-related deaths, while weak tornadoes caused only 1% of tornado-related deaths. If the data prior to 1950 is examined, the percentage of deaths attributable to violent tornadoes climbs drastically. That is largely due to the fact that tornado forecasting and awareness programs were not yet established. As a result, it was much more likely for death tolls from a single tornado to reach several hundred.

Maps and tables at the end of this section show the breakdown of tornadoes by county for the period from 1950 to 2009, and also for the more recent period from 1996 to 2013. An examination of the map and tables indicates that tornadoes occur more frequently in the southern-half of the Lower Peninsula than any other area of the state. This

area could be referred to as Michigan's "tornado alley." Most tornadoes in Michigan come from the southwest and travel northeast, with many passing through the most densely populated areas of the state.

Records indicate that tornadoes in Michigan have been more deadly than in many other tornado-prone states. Part of that is influenced by the high death toll associated with the June 8, 1953 and April 11, 1965 tornadoes. However, part is also due to the fact that several tornadoes have hit relatively densely populated areas of Michigan, increasing the fatalities. As for when those deaths occurred, the table below provides a good indicator, based upon about 55 years of events, and reveals that 96% of the state's tornado-related deaths have occurred in the months of April, May and June. June has been Michigan's most deadly tornado month, with 54% of all deaths. If the June 8, 1953 tornado death toll of 115 people is excluded, April becomes the most deadly tornado month with 77 deaths (32% of the total). Note that a tornado can sometimes appear during winter months.

### **Tornado-Related Deaths in Michigan, by Month: 1950-May 2005**

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
0	0	3	77	23	130	3	1	1	0	1	0	239

Source: National Climatic Data Center

In Michigan, tornadic activity is a real threat; there were 954 tornadoes reported from 1950 to 2005. There have been 239 related deaths, but fewer than 10% of these occurred after 1980, probably due to improved warning systems and public knowledge of the threats. Although there have been fewer deaths and injuries recently, property damages have remained very heavy, though not consistently predictable. As recent tornado events in Joplin, MO (2011) and Norman, OK (2013) showed, it is still possible to have a destructive tornado directly impact urbanized areas, as had occurred in Michigan's worst 1953 event.

The geographic risk for tornadoes in Michigan is far greater in the southern half of the state than in the northern half. All counties south of Kent and Genesee Counties have had at least 14 tornadoes touch down in their boundaries from 1950-2009 (with the exception of St. Joseph County, having only 9 tornadoes). Genesee (41), Lenawee, Kent and Oakland Counties (31 each) have had the highest total of tornadoes in the state. When adjusting for the size of the county, the highest-risk counties on a per-land area basis becomes Genesee (10.5 tornadoes per 10,000 square miles), Monroe (8.4), and Ingham and Berrien (8.0 each). North of Flint and Grand Rapids, only Saginaw County has had a relatively high occurrence of tornadoes, with 21. The extreme northern portion of the Lower Peninsula and the Upper Peninsula overall have a lower risk of tornadoes, with all counties having 11 or fewer tornadoes (although Alpena and Ogemaw had 14) over the 60-year time span. Nevertheless, the tornado impact can be disastrous for any Michigan county. Oscoda County, which has a relatively low frequency of tornadoes, suffered devastating damage from a tornado strike at the town of Comins, in 1999.

Although tornadoes technically cannot be prevented, contained, or completely predicted, their potential impacts on Michigan's citizens and communities can certainly be reduced. In general, improved surveillance and warning systems implemented by the National Weather Service and emergency management agencies, coupled with extensive public education campaigns, have been very effective in keeping the death toll down in recent years. However, this is not to say that a major death toll could not occur again if a strong tornado should strike a highly populated area. History has clearly shown that tornadoes must always be treated with the utmost respect and caution. Other initiatives, such as structural bracing, urban forestry practices, manufactured home anchoring, and strengthening electrical system components, can help to reduce public and private property damage.

Like severe straight-line wind events, tornado disasters require that communities plan and prepare for the mass care of residents left without electrical power and the clearance and disposal of tree and construction debris from roadways. Those are the two primary challenges facing Michigan communities. The planning and preparedness effort should include the identification of necessary mass care facilities and supplies, as well as debris removal equipment and services. In addition, communities should develop debris management procedures (to include the

identification of multiple debris storage, processing and disposal sites) so that the debris stream can be handled in the most expedient, efficient, and environmentally safe manner possible.

National Weather Service data indicates that Michigan has experienced 923 tornadoes and 242 related deaths during the period from 1950 to 2009, an average of 15 tornadoes and 4 tornado-related deaths per year. The greatest number of tornadoes per year during that period occurred in 1974, with 39 tornadoes (8 of which occurred on April 3). The least number occurred in 1959, with only 2 tornadoes. From 1950 to March 2005, Michigan experienced 508 “tornado days” (defined as days in which tornadoes are observed), an average of 9 days per year.

The map and table at the end of this section list the number of tornadoes experienced in each Michigan county for the period 1950-2009. (Note: these totals do not correct for boundary-crossing tornadoes; therefore, a tornado that crosses a county boundary will be “double counted” in the totals for each county.)

All counties south of Kent and Genesee Counties have had at least 14 tornadoes touch down in their boundaries from 1950-2009 (with the exception of St. Joseph County, having only 9 tornadoes). Genesee (41), Lenawee, Kent and Oakland Counties (31 each) have had the highest total of tornadoes in the state. When adjusting for the size of the county, the highest-risk counties on a per-land area basis become Genesee (10.5 tornadoes per 10,000 square miles), Monroe (8.4), and Ingham and Berrien (8.0 each). North of Flint and Grand Rapids, only Saginaw County has had a relatively high occurrence of tornadoes, with 21. The extreme northern portion of the Lower Peninsula and the Upper Peninsula overall have a lower risk of tornadoes, with almost all counties having 11 or fewer tornadoes (although Alpena and Ogemaw had 14) over the 60-year time span. Nevertheless, the tornado impact can be disastrous for any Michigan county.

In terms of intensity, Michigan’s tornado experience since 1950 has essentially mirrored the national experience. Approximately 67% of all Michigan tornadoes have been weak tornadoes (EF0 or EF1 intensity), while 29% have been strong tornadoes (EF2 or EF3 intensity) and 4% have been classified as violent tornadoes (EF4 or EF5 intensity). However, those few violent tornadoes have been responsible for 88% of Michigan’s tornado-related deaths. Strong tornadoes (EF2 or EF3 intensity) have accounted for approximately 11% of the deaths, while weak tornadoes (EF0 or EF1 intensity) have caused only 1% of all tornado-related deaths. Those patterns are fairly consistent with the national averages, although Michigan has had more strong and violent tornadoes (approximately 33% in Michigan vs. 27% nationally), and its death toll from violent tornadoes is slightly higher than the national average (67% in Michigan vs. 65% nationally). Michigan’s higher than average death toll from violent tornadoes is largely due to the tragic storm events that occurred in Flint in 1953 and across southern Michigan in 1965 (see the Significant Tornadoes section for more details). Unfortunately, Michigan’s tornado experience to date has been more deadly than in many other tornado-prone states across the country. Michigan’s tornado events have earned it a top ten ranking in three national tornado statistical categories: (1) single killer tornadoes, (2) deaths per 10,000 square miles, and (3) killer tornadoes as a percent of all tornadoes.

### Killer Tornadoes: Selected Top Ten Lists

Rank	Single Killer Tornadoes (Date, State, # Deaths, F-Scale)	Tornado Deaths Per 10,000 Sq. Miles	Killer Tornadoes as % of all Tornadoes
1	March 18, 1925, MO-IL-IN, 695 deaths, F5	Massachusetts	Tennessee
2	May 7, 1840, LA-MS, 317 deaths, F?	Mississippi	Kentucky
3	May 27, 1896, MO-IL, 255 deaths, F4	Indiana	Arkansas
4	April 5, 1936, MS, 216 deaths, F5	Alabama	Ohio
5	April 6, 1936, GA, 203 deaths, F4	Ohio	Alabama
6	April 9, 1947, TX-OK-KS, 181 deaths, F5	<b>Michigan</b>	Mississippi
7	May 22, 2011, MO, 158 deaths, F5	Arkansas	North Carolina
8	April 24, 1908, LA-MS, 143 deaths, F4	Illinois	<b>Michigan</b>
9	June 12, 1899, WI, 117 deaths, F5	Oklahoma	New York
10	<b>June 8, 1953, MI, 116 deaths, F5</b>	Kentucky	Massachusetts

Source: NOAA <http://www.spc.noaa.gov/faq/tornado/killers.html> ; The Tornado Project / National Weather Service

Michigan's tornado death toll is significantly influenced by two disasters: one in Flint on June 8, 1953 that caused 115 deaths and \$19 million in damage, and a series of tornadoes in southern Michigan on April 11, 1965 (Palm Sunday) that caused 53 deaths and \$51 million in damage. (See the tables below and on the following pages for more information on these and other significant tornadoes in Michigan.) Fortunately, the trend over time has generally been toward a lesser number of tornado deaths. During the 1950s, 153 deaths occurred, when the total number of tornadoes recorded was 109. In the 1960s, the number of deaths dropped to 66 although the number of tornadoes went up a bit, to 123. In the 1970s, despite a whopping 251 tornadoes, only 8 deaths resulted, and the trend has stayed quite low ever since. The 1980s saw 10 tornado deaths and 212 tornado events, but the 1990s saw only 2 deaths among 173 events. During the 2000s, a total of 3 deaths occurred, and the total number of events numbered 160.

A list of tornadoes, by county, for the years 1950 to 1995, can be found here: <http://www.tornadoproject.com/alltorns/mitorn.htm>, while a list of tornado events from 1996 to present can be obtained from this online database (the source of a table at the end of this section): <https://www.ncdc.noaa.gov/stormevents/>

Since 1996, Michigan has averaged about 16 tornadoes per year. An average of about 4 tornado deaths and 60 injuries takes place each year, in Michigan (when using historical data back to 1950). Annual property damage averages more than \$19 million per year, based upon events from 1996-2013. (NOTE: As with other weather events, these figures are conservative, actual totals are likely to be higher.) Higher-risk regions of Michigan are noted in the maps and tables at the end of this section. Personal and site vulnerabilities tend to vary by the engineering of each particular type of structure.

#### Impact on the Public

Tornadoes are rightfully dreaded as the most severe windstorms to which most of Michigan is vulnerable. Ordinary public activities must be curtailed in order to avoid extreme danger of injury and death either from the force of the winds themselves (which have the capacity to lift persons, heavy objects, or even structures and throw them great distances), or from the impact of objects that are being thrown forcefully around by the storm. Sheltering needs are compounded by the danger of broken and flying glass—to best ensure residents' safety, it is necessary to find the most secure area possible within a structure or affected area. An underground or specially reinforced, window-free room is usually required to guarantee personal safety (sometimes at considerable economic expense). The effects of a strong tornado may disrupt normal community functions for some time, or even cause a small community to be practically destroyed. Tornadoes cause more annual injuries, on average, than any other Michigan hazard except for structural fires.

#### Impact on Public Confidence in State Governance

When infrastructure failures occur, as from the impact of tornadic winds, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. For example, an assumption might be made by some that the burying of power lines should be undertaken (or required by legislation), even if it involves considerable expense, whereas a full consideration of the tradeoffs involved in such burial (e.g. greater difficulty in locating and repairing a broken line) may not have been considered. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

#### Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impact of winds. Fortunately, tornado events tend to be

rather brief, but their unpredictability, and their difficulty of detection and avoidance, exacerbates the existing challenges involved in emergency response. Impeded traffic, power failures, debris, and road closures often make responses and the use of equipment much more difficult.

#### **Impact on the Environment**

Tornadoes are dangerous violent rotating columns of winds that can produce wind speeds from 73 to more than 300 miles per hour, and can cause severe environmental damage. Damage to the environment includes debris, fires, and chemicals from damaged and destroyed structures, vehicles, and infrastructure, which can be scattered for miles. Building materials, chemicals, smoke, sewage, and machinery can land in and cause harm to forests, valleys, streams, lakes, rivers, and wildlife species. Animals (including domesticated livestock) and other organisms can be killed or injured in the event of a tornado. Trees can easily be uprooted, branches broken off, and entire woodlands can be destroyed by tornado impacts. Rural settings can be damaged and plants can be carried to different parts of land for seeding where they otherwise would not have been. There is also an increased threat of fire in areas where dead trees are not removed in a timely matter.

The most dangerous type of environmental impact would be when a tornado strikes a facility that contains potentially hazardous or toxic materials, farm chemicals, trash in a local landfill, medical waste awaiting disposal, or radioactive materials. Not only can material be spread around the immediate site where the tornado strikes, a small (but important) fraction can be carried aloft and transported a great distance down streams or rivers. There is also a possibility that tornadoes can cause the spread of diseases, or fungi found in certain soils. Gas lines can also be ruptured and harm local air quality as well as cause environmental damage by seeping into the soil, rivers, lakes, and streams.

#### ***Climate Change Considerations***

According to the National Oceanic and Atmospheric Administration, there is no known way to predict whether or how climate change is affecting thunderstorm and tornado frequency or severity. These types of weather events involve a different scale of phenomenon than climate change, and models of the latter have not yet been able to predict local trends in the former (<http://www.spc.noaa.gov/faq/tornado/>).

#### ***Significant Tornadoes in Michigan***

##### **May 25, 1896 – Oakland and Lapeer Counties**

One of the mere handful of F5 intensity tornado events to be recorded in Michigan's state history, this event resulted in 47 deaths and 100 injuries, as the communities of Ortonville, Oakwood, and North Oxford suffered from the touchdown of this monstrous storm.

##### **June 5, 1905 – Sanilac and Tuscola Counties**

This was the second of Michigan's few recorded tornadoes that were measured as a full F5 intensity level. Five persons were killed and 40 were injured.

##### **June 6, 1917 – Kalamazoo County**

A deadly tornado struck the Climax and Cass Lake areas very hard, resulting in 4 deaths and 50 injuries.

##### **March 28, 1920 – Genesee County**

Another deadly tornado event, this time impacting Fenton and Flint most heavily, caused 14 deaths.

##### **May 21, 1953 – St. Clair County**

Two persons were killed, and 68 injured, as an F4 tornado left a path 10 miles long and 1 mile wide. The total damage was estimated at \$2.5 million.

##### **June 8, 1953 – Flint (Genesee County)**

The June 8, 1953 Flint tornado, Michigan's worst storm to date (and classified as F5), is ranked 10th on the top ten list of single killer tornadoes that have occurred in the United States. It was also the last single tornado, until the May 2011 Joplin, MO EF5 tornado, to cause over 100 deaths in the U.S. The storm began its destructive path approximately two miles north of Flushing, moved east-northeast and devastated the north part of Flint before ending two miles north of Lapeer. The tornado obliterated homes on both sides of Coldwater Road for about one mile. It was there that most of the deaths occurred and the damage swath was over one-half mile wide. There were multiple deaths in at least 20 families. The final death toll stood at 115 in Flint alone, along with 785 injuries and total damage estimated at \$19 million. Several tornadoes touched down in other locations in Michigan on that day as well, resulting in an additional six deaths and 129 injuries statewide.

##### **April 3, 1956 – Hudsonville/Standale (Ottawa and Kent Counties)**

In 1956, a category F5 tornado struck first at Hudsonville, then traveled northeast and plowed through both Ottawa and Kent Counties, killing 14 and injuring 200. (Some sources cite 17 deaths and 300 injuries.) Over 700 homes were destroyed. Numerous other tornadoes classified as F4 took their toll on other counties such as Manistee (2 killed, 24 injured), Grand Traverse, Benzie, and Allegan.

##### **May 12, 1956 – Flint**

Three persons were killed and 116 were injured as a result of an F4 tornado. On the same day, an F4 tornado also touched down in Wayne County, injuring 22 persons.

### July 4, 1957 – Livingston and Oakland Counties

Six persons were injured in Livingston County, when F4 tornadic activity took place around the dinner hour. Oakland County was also impacted.

### May 8, 1964 – Macomb County

Although numerous tornadoes occurred throughout the Lower Peninsula on this date, the worst impact was in Macomb County, where 11 persons were killed, 224 were injured, and an estimated \$2.5 million in property damage was caused.

### April 11, 1965 - Southern and Central Michigan

The April 11, 1965 Palm Sunday tornado outbreak, which affected many other states in the Midwest, had a particularly devastating impact on Michigan. As the following table indicates, a total of 23 tornadoes touched down in 14 southern and central Michigan counties, resulting in 53 fatalities, 798 injuries, and \$51 million in damage to public and private property. Many of the tornadoes were rated F3 and F4 in intensity (strong and violent tornadoes), which undoubtedly contributed to the high death and injury tolls. Across the Midwest, this storm system spawned 47 confirmed tornadoes that collectively killed 271, injured 3400, and caused an estimated \$200 million in property damage. In addition to Michigan, the other states that were affected by the storms included Indiana, Illinois, Ohio and Wisconsin. One of the tragic Michigan impacts was at Manitou Beach (Hillsdale-Lenawee County), where storms stuck a church with many persons inside.

#### April 11, 1965 (Palm Sunday) Tornado Outbreak: Michigan Impacts

County	Number of Tornadoes	Deaths	Injuries	Tornado Intensity
Allegan	1	1	9	F1
Barry	2	0	5	F1 and F3
Branch	2	18	400	F3 and F4
Clinton	1	1	8	F4
Gratiot	4	0	1	all F2
Hillsdale	2	6	94	F3 and F4
Kalamazoo	1	0	17	F3
Kent	1	5	142	F4
Lenawee	2	9	83	F3 and F4
Monroe	3	13	39	F3 and F4
Montcalm	1	0	0	F2
Ottawa	1	0	0	F4
Shiawassee	1	0	0	F4
Tuscola	1	0	0	F2
<b>STATEWIDE TOTALS:</b>	<b>23</b>	<b>53</b>	<b>798</b>	<b>2 F1 tornadoes; 6 F2 tornadoes; 6 F3 tornadoes; 9 F4 tornadoes</b>

Source: The Tornado Project / National Weather Service

### April 21, 1967 – Southwestern and South-Central Lower Peninsula

Numerous twisters caused many injuries and extensive property damage across more than a dozen counties. Fortunately, there were no known fatalities, but NCDC records indicate a total of 51 persons injured and more than \$28 million in property damage. A touchdown in Clinton County was of F4 intensity.

### July 4, 1969 – Southeastern Michigan

Numerous tornado events marred the 1969 Independence Day holiday in Michigan. Although no fatalities were reported, 65 persons were injured across Jackson, Washtenaw, and Wayne Counties. Damage estimates exceeded \$5 million.

### April 3, 1974 – Southeastern Michigan

After a number of years without any Michigan fatalities from tornadoes, disaster struck full force in 1974. Two persons were killed and 43 injured when numerous tornadoes touched down in Monroe, Hillsdale, Lenawee, and other counties. Damages totaled nearly \$3 million. Although a downward trend in fatalities and injuries had been observed in each decade since the 1950s, Michigan residents were again reminded about the deadly severity of its tornado hazard, and the sheer number of tornadoes was very large at this time. This date is also notable, nationally. National Weather Service data reports a total of 239 tornadoes across the United States on this day—8 of which were in Michigan, 16 in Ohio, and 54 in Indiana! Nationally, 308 persons were killed by tornado impacts on this single day, 5,416 were injured, and property damages amounted to \$1.5 billion. This “super outbreak” broke records as being the largest number of tornadoes to strike the United States in a single day.

### March 20, 1976 – Southeastern Michigan

Most of the Lower Peninsula’s residents were threatened by severe weather on this day, but as the dinner hour arrived in Oakland and Macomb Counties, a pair of tornadoes of F4 and F3 severity caused the weather impacts to turn deadly. Two persons were killed and 58 were injured. Nearly \$26 million in property damage was also tabulated.

### April 2, 1977 – Kalamazoo and Eaton Counties

Ten were injured in Kalamazoo, and then one person was killed and 44 injured in Eaton County. The tornado intensity was categorized as F4.

### May 13, 1980 - Kalamazoo and Van Buren Counties

On May 13, 1980 two tornadoes occurred in southwest Michigan – one in Van Buren County and one in Kalamazoo. The Van Buren County tornado damaged over 500 structures and injured 15 persons. The Kalamazoo tornado damaged over 1,200 homes and caused five fatalities and 79 injuries. This was the greatest number of persons killed by a single tornado in Michigan since the April 11, 1965 occurrence. Damage in the two counties was so severe that a Presidential Major Disaster Declaration was granted to provide supplemental federal disaster assistance to those communities and individuals significantly affected by the storms. More than \$50 million in damages were caused by these tornadoes.

### **July 4, 1986 – Menominee County**

Another disastrous tornado event injured 12 and caused an estimated \$2.5 million in property damage during the early evening on the Independence Day Holiday.

### **June 21, 1987 – Novi (Oakland County)**

An F2 tornado caused 1 death, 6 injuries, and \$250,000 in property damage.

### **October 4, 1990 - Genesee County**

On October 4, 1990 an F2 intensity tornado touched down in Flint, Burton, and Davison Township in Genesee County, leaving a trail of destruction approximately 200 yards wide and four and one-half miles long. Over 30 homes and 20 businesses were severely damaged, and numerous roads and streets were blocked due to fallen trees and debris. One person was injured when his tractor-trailer was overturned by the strong winds while traveling on Interstate 69 in Burton. Total damage was estimated at \$2 million. A Governor's Disaster Declaration was granted to provide supplemental state financial assistance to help pay for the cleanup costs associated with the storm.

### **March 27, 1991 – Entire Lower Peninsula**

Severe weather events covered a wide area and produced numerous tornadoes across many Northern Lower Peninsula counties. Ogemaw, Iosco, and Alcona Counties were particularly hard-hit, and suffered a total of more than \$5 million in property damage from F3 tornadoes that traveled dozens of miles. The Southern Lower Peninsula was also plagued by tornado impacts, including an F3 touchdown in Calhoun County that injured 18 persons, and an F3 tornado in Hillsdale County that caused \$25 million in property damage.

### **April 16, 1992 - Plymouth (Wayne County)**

On April 16, 1992 an F2 intensity tornado touched down in a mobile home park near Plymouth. The tornado destroyed 6 homes and damaged 14 others. Four residents of the mobile home park were injured. Total property damage was estimated at \$2.5 million.

### **July 13, 1992 - Cass County**

On July 13, 1992 an F2 intensity tornado touched down in northwest Cass County, leaving a trail of destruction one-half to one mile wide and six miles long. The tornado damaged or destroyed 40 homes, several agribusinesses, and one migrant labor camp. 25 persons were injured, and another 100 were left homeless by the tornado. Damage was estimated at \$3.5 million, with nearly \$2.7 million of that total being agricultural damage. A Governor's Disaster Declaration was granted to provide supplemental state assistance with security, sheltering and mass care.

### **July 2, 1997 - South-Central and Southeast Michigan**

On July 2, 1997 a series of intense thunderstorms went through south-central and southeast Michigan. These storms spawned a total of 16 tornadoes, 13 of which occurred in the southeastern Michigan counties of Genesee, Lapeer, Livingston, Macomb, Oakland, Saginaw and Wayne. The total for southeast Michigan is the highest number for a single day since records have been kept from 1950. The tornadoes damaged or destroyed over 2,900 homes and nearly 200 businesses, and caused over \$25 million in public damage and nearly \$30 million in private damage. A total of 16 deaths were attributed to this storm front, but only 2 of those deaths were caused by the tornadoes. Another 120 persons were injured in the storm event (98 from tornadoes). The tornadoes and straight-line winds downed thousands of trees and power lines, which knocked out power to 350,000 electrical customers and caused significant public health and safety threats. Subsequent analysis by the National Weather Service indicated that the Wayne County tornado was F2 in intensity, while in Genesee County there were two F3 tornadoes and two F1 tornadoes. The remaining tornadoes were either F0 or F1 in intensity. A Presidential Major Disaster Declaration was granted for the five counties most severely impacted by the tornadoes and severe thunderstorms.

### **October 6, 1998 - Big Rapids (Mecosta County)**

On October 6, 1998 a series of strong thunderstorms traveled through several counties in central Lower Michigan. The City of Big Rapids, in Mecosta County, was hardest hit by the storms. Officials from the National Weather Service determined that an "F-1 mini tornado," with winds reaching 80-90 miles per hour, had struck the Ferris State University campus, damaging several buildings and numerous surrounding residences and vehicles. The storm also downed trees and power lines in the area, and injured seven persons. The storm track was approximately 150 feet wide and one mile long. The storm dumped nearly 3 inches of rain in the Big Rapids area, flooding many streets and parking areas. In nearby Clare County, the storm destroyed one home, damaged ten others, and injured three persons.

### **July 3, 1999 - Comins (Oscoda County)**

On July 3, 1999 a tornado touched down near Lewiston in Montmorency County and traveled southeast for twenty-one miles through Oscoda and Alcona Counties, causing damage to homes and businesses and injuring two persons. The hardest hit areas included the Village of Comins and Clinton Township in Oscoda County. The destruction was devastating – 80 percent of the Village of Comins was damaged or destroyed by the storm. Nine homes were destroyed, 46 homes sustained damage, and eight businesses were damaged or destroyed. The Clinton Township Hall and Fire Department buildings were also destroyed, and the Post Office sustained damage. Local roads were blocked by debris and downed power lines, leaving residents without power for several days. Only three buildings in town – a bar, a party store, and a senior center – were left standing intact. After striking Comins, the storm continued on its path and damaged another 20 residences at nearby Crooked Lake in Alcona County. A Governor's Disaster Declaration was granted to Oscoda County to provide supplemental state assistance with debris removal, clean up, and traffic control. Damage estimates approached \$2 million.

### **May 21, 2001 - Southern and Central Michigan**

On the afternoon of May 21, a line of severe thunderstorms moved across Michigan, spawning 21 tornadoes in 16 counties and causing damage in all but one of those counties. The hardest hit counties were Kalamazoo, Kent, Livingston and Oakland. Fortunately, no deaths or serious injuries occurred as a result of these storms. All totaled, the tornadoes caused about \$5.5 million in property damage and \$400,000 in agricultural crop damage. The largest share of the property damage – approximately \$3 million – was caused by an F2 intensity tornado that struck Hartland and Tyrone Townships in Livingston County. The tornado tore through a golf course, destroying 12 vehicles and damaging 58 others, destroying 35 golf carts and a portion of the clubhouse, and injuring one person. The tornado also destroyed three nearby homes and two businesses, damaged another business, and downed hundreds of trees in the area. Several cars and semi-trailers were flipped and damaged when the tornado crossed U.S. 23.

### **September 9, 2001 - Delta Township (Eaton County)**

In the late afternoon hours of September 9, 2001 an F1 intensity tornado carved an 8-mile long by 900-yard wide swath of destruction through Delta Township in Eaton County. The tornado – packing winds of up to 110 miles per hour – destroyed the cooling towers at a Lansing Board of Water and Light power plant, causing \$4 million in damage and forcing the plant to shut down its operations. The tornado also destroyed a business and damaged several others in an industrial park, damaged dozens of homes and barns, and downed numerous trees and power lines. Even though the tornado crossed three Interstate Highways and passed several housing subdivisions along its path, it did not cause any deaths or serious injuries.

### **September 30, 2002 - Southeast Upper Peninsula**

On September 30, 2002 a supercell produced three tornadoes and extensive downburst wind damage in southern Dickinson County. The majority of damage to the Iron Mountain, Kingsford and Quinnesec areas was caused by downburst winds, which knocked trees into homes, downed power lines, etc. The most significant damage was produced by the tornado that moved through Kingsford and Iron Mountain. An F1 intensity tornado developed in Florence County, Wisconsin and crossed the Menominee River just south of the Iron Mountain-Kingsford airport. Numerous trees and power lines were knocked down, blocking highway US-2 and disrupting electric power and telephone service. Gas lines were ruptured and several commercial buildings sustained substantial roof damage in Kingsford. Property damage due to all of the storms was estimated at around \$7 million.

#### **July 20, 2003 - Battle Creek (Calhoun County)**

An F1 intensity tornado struck Calhoun County during the afternoon of July 20th, 2003. The tornado first touched down on the southeast side of Battle Creek. It lifted for several miles but eventually touched down again. It stayed on the ground for approximately three miles and intensified, causing a garage to be torn from a house and an older farm house to be rotated and pushed off its foundation. Three outbuildings and a barn were also destroyed. Roof shingle damage was also noted to other houses in the area. Hundreds of trees were uprooted or broken off. The tornado path was eight miles long from where it first touched down to where it lifted for the last time. The tornado width was nearly one half mile wide where the most severe damage occurred. The tornado caused nearly \$1 million in property damage along with \$200,000 in crop damage.

#### **August 21, 2003 - Ingham County**

On August 21, 2003 a tornado struck eastern Ingham County. The tornado's path length was 4.5 miles long and it was up to 1/2 mile wide. It was on the ground for 15 minutes and was rated as a lower F2 on the original Fujita scale. A severe thunderstorm warning was issued for Ingham County and that was soon upgraded to a tornado warning. Two homes were destroyed. One house collapsed and trapped two individuals inside, injuring both. At another location, a house was damaged and a barn was leveled, and a pickup truck was blown off the road. Tornado-related property damage was relatively low, but crop damage was estimated at \$200,000.

#### **August 24, 2007 – Eaton County**

An EF3 tornado with wind speeds estimated at 140 mph produced its most severe damage along a path from M-50 just north of Kinsel Highway to just west of M-100 and Vermontville Highway near Potterville. A NWS storm survey indicated a tornado path which was 200 to 300 yards wide and 6.5 miles long. Fifteen homes were either destroyed or severely damaged. A roof was blown off a single-story home and windward-facing walls were blown in. The majority of the roof and garage from this home were not found. A roof was blown off a two-story home and the upper story front walls were blown in. Additional damage included the partial collapse of the upper story of a home, and another house was blown off its foundation. Two barns were destroyed and another incurred heavy damage just west of Potterville. Six persons were injured, and property damages totaled more than \$25 million.

#### **October 18, 2007 – Ingham County and Northern Lower Peninsula**

A tornado occurred at night, and based on extensive damage to buildings and trees, it was classified EF2, with top winds estimated between 120 and 130 mph. The tornado began just northeast of Mason around 10:28 pm EDT and moved northeast at 40 to 45 mph through the City of Williamston between 10:40 and 10:45 pm. Approximately 100 structures were damaged in a subdivision on the south side of Williamston. Two fatalities occurred about 4 miles northeast of Williamston, where a modular home and its two occupants were flipped into a pond. The tornado then moved into Shiawassee County and dissipated shortly thereafter. Total property damages were estimated as nearly \$20 million.

A historic tornado outbreak also rocked Northern Lower Michigan on the afternoon and evening of October 18, 2007. Northern Lower Michigan had a record six tornadoes on the day. The previous high was five, set on June 17, 1992. Unfortunately, a Kalkaska tornado produced a fatality. That was the first tornado fatality in Northern Lower Michigan since March 30 1976, when a single death had occurred in Ogemaw County.

#### **June 6, 2010 – Monroe and Lenawee Counties**

Two tornadoes struck Monroe County, one classified as EF2 and the other as EF1. The stronger tornado was up to 800 yards wide and tracked 13 miles across Monroe County, including movement through the Village of Dundee, which was the hardest-hit location (after which the tornado weakened to EF0 levels in its east-southeastern course). The weaker tornado was up to 500 yards wide and tracked 5 miles from the Woodland Beach area to the northeast, reaching Estral Beach and proceeding out into Lake Erie. The weaker tornado was especially significant for two reasons—it caused some damage at the Fermi nuclear power facility, and it also impacted an area that is a project site for flood mitigation activities (at Estral Beach). The tornado damaged more than 125 homes and 23 vehicles, and set back a significant amount of flood mitigation project work in the area. Estimated damages from the weaker tornado amounted to \$10 million. Estimated damages from the stronger tornado were \$50 million. A total of 311 buildings were damaged in Monroe County, and 5 houses were destroyed. A weaker F1 tornado also caused \$500,000 in damage to property in adjacent Lenawee County.

#### **June 27, 2010 – St. Clair County**

Among the tornado damages this day was a disastrous strike at a campground just north of I-69 and west of Wadhams Road in Clyde Township. One person was killed and four were injured. The tornado was classified as EF1, with winds up to 95 mph. About 10 campers were damaged or destroyed, including being blown into the water of a large pond nearby. Total damages at that location were estimated at \$700,000. Total tornado damages that day amounted to more than \$1.25 million.

#### **April 26, 2011 – Allegan County**

An EF-0 tornado (with winds peaking near 85 mph) damaged buildings from the Deboer Turkey Farm to trailers near Burnips (Allegan County). The tornado tore a small section of roof off a warehouse building, knocked over several trailers, and blew the windows out of several cars, then uplifted and collapsed an approximately 100-foot section of pole-barn. The roof was torn off about a 50-foot section of another barn. To the northeast, several small outbuildings were destroyed and trees were uprooted. Several houses received minor roof, soffit, and garage door damaged. The tornado lifted after partially destroying a 75 year-old barn. The property damage totaled approximately \$1M.

#### **May 29, 2011 – Calhoun County**

Three tornadoes produced wind gusts up to 100mph in the southern Lower Peninsula, resulting in several uprooted trees and downed power lines. 163,000 homes and businesses were without power. The Battle Creek area was hit the hardest, with straight line winds between 75 and 100mph, causing wide-spread damage. The event resulted in a Governor's disaster declaration for Calhoun County, no deaths or serious injuries were reported.

#### **March 15, 2012 – Southeast Michigan (Washtenaw, Lapeer**

Three tornadoes resulted in a total of \$12M in property damage. Fortunately, there were no reported deaths or injuries. An EF-3 tornado touched down near Dexter (Washtenaw County), with maximum wind speeds of 135-140 mph. The tornado damaged at least 200 homes (20 severely), and destroyed two more. An EF2 tornado (with maximum wind speeds of around 125mph) struck approximately 5 miles northwest of Lapeer, leaving a damage path roughly 4.6 miles long with a maximum width of 400 yards. Damage included a destroyed garage, a house shifted off its foundation, uprooted trees and other minor structural damage. An EF0 tornado with maximum wind speeds of 85mph was confirmed in central Monroe County, near Yargerville. The estimated path length of this tornado was 0.5, miles with a maximum width of 50 yards. The damage consisted of siding and shingles blown off a house, a tipped car, a shed destroyed, and trees blown down.

## Other Recent Significant Tornado Outbreaks of General Interest in the United States

### **April 2011 – National Outbreak**

April 2011 shattered the previous April tornado record of 267 tornadoes set in April 1974 by producing 677 confirmed tornadoes (875 were reported) across the United States. The previous record for any month was 552 tornadoes in May of 2003. In particular, from April 25-28, 2011 there were 362 tornadoes, breaking the previous single tornado outbreak record of 148 tornadoes on April 3-4, 1974. The 361 people killed during the April 2011 outbreak set a new record, with 322 of those deaths occurring during the April 25-28, 2011 time frame alone. There were four EF5 tornadoes during this particular outbreak. The biggest loss of life for a single tornado occurred in Tuscaloosa-Birmingham, Alabama, with at least 65 fatalities. This tornado, rated an EF5, had a maximum width of 1.5 miles and a track 80 miles long. Although the numbers with this single tornado are impressive, the deadliest single tornado on record in the United States still is the Tri-State tornado (Mo., Ill., Ind.) on March 18, 1925, when 695 died.

### **May 2011 – Joplin, MO**

One month after the April 2011 national outbreak occurred, another deadly single tornado occurred in Joplin, Missouri, resulting in 158 fatalities and 990 injuries on May 22, 2011. This Joplin, Missouri tornado is only the second EF5 tornado to occur in Missouri since 1950. The tornado resulted in being the costliest disaster in Missouri history, at over \$2.8 billion.

### **May 2013 – Oklahoma**

An EF5 tornado swept across the southern part of the Oklahoma City metropolitan area, destroying many structures along a 17 mile-long path that was more than 1 mile wide and most strongly hit the city of Moore, OK. According to <http://www.srh.noaa.gov/oun/?n=tornadodata-okc-table>, 24 deaths, including 7 children when a school wall collapsed, and more than 300 destroyed homes resulted. On the previous day, an EF4 tornado had struck nearby Norman, OK, killing two persons. Widespread media coverage took place as these events happened.

## ***Programs and Initiatives***

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from severe straight-line winds have the dual purpose of also protecting against tornadoes. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

## National Weather Service Doppler Radar

The National Weather Service has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including tornadoes and the severe storms that spawn them. Most important, the lead time and specificity of warnings for severe weather have improved significantly.

Doppler technology calculates both the speed and the direction of motion of severe storms. By providing data on the wind patterns within developing storms, the new system allows forecasters to better identify the conditions leading to severe weather such as tornadoes and severe thunderstorms. This means early detection of the precursors to severe storms, as well as information on the direction and speed of storms once they form.

## National Weather Service Watches/Warnings

The National Weather Service issues tornado watches for areas when the meteorological conditions are conducive to the development of a tornado. People in the watch area are instructed to stay tuned to NOAA weather radio and local radio or television stations for weather updates, and watch for developing storms. Once a tornado has been sighted and its existence is confirmed and reported, or Doppler Radar shows strong probability of the development or occurrence of a tornado, the National Weather Service will issue a tornado warning. The warning will identify where the tornado was sighted, the direction in which it is moving, and the time frame during which the tornado is expected to be in the area. Persons in the warning area are instructed to seek shelter immediately.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), National Oceanic and Atmospheric Administration (NOAA) weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet at [www.weather.gov](http://www.weather.gov), where an interactive map can be used.

### Public Warning Systems

Numerous communities in Michigan have outdoor warning siren systems in place to warn the public about impending tornadoes and other hazards. Most of these systems were originally purchased to warn residents of a nuclear attack, but that purpose was expanded to include severe weather hazards as well. These systems can be very effective at saving lives in densely populated areas where the siren warning tone is most audible. In more sparsely populated areas where warning sirens are not as effective, communities are turning to NOAA weather alert warning systems to supplement or supplant outdoor warning siren systems. Unfortunately, a large number of communities across the state do not have adequate public warning systems in place to warn their residents of severe weather or other hazards. Federal funding specifically allocated to assist communities in the purchase of public warning systems has effectively disappeared, leaving many communities unable to purchase adequate systems to warn their residents of impending danger.

Attempting to fill some of that funding void, the State of Michigan has used federal Hazard Mitigation Grant Program (HMGP) funds to assist local communities in purchasing public warning systems. To date, HMGP funds have been used to purchase and install more than 80 outdoor warning sirens, over 1,000 NOAA weather alert monitors for schools, hospitals and places of public assembly, four NOAA weather radio transmitters, and several other early warning systems. Communities that received funding for these projects were encouraged to implement a warning education program to ensure that residents know what to do once they receive warning of an impending hazardous event. Because HMGP funds must be used to fund a wide variety of mitigation projects, the amount of funds available to fund warning systems is limited to a small percentage of the overall available grant funds allocated to the state. The HMGP funds are provided on a 75% federal, 25% local cost share. A Presidential major disaster declaration is required to activate the HMGP funding. As a result, the funding stream may not always be available in the future. In addition, state mitigation priorities may change over time, putting public warning systems at a lower priority than other mitigation projects. However, the HMGP does provide at least one possible avenue for assisting communities in enhancing their local public warning capability.

### Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week. This annual public information and education campaign focuses on severe weather events such as tornadoes, thunderstorms, lightning, hail, high winds and flooding. The purpose of the tornado portion of this campaign is to inform the public about what tornadoes are and when they usually occur, what they should do if a tornado occurs, what community warning systems exist, and to provide other pertinent tornado-related information as appropriate. Informational materials are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public. Special educational programs are often conducted during this week.

### Manufactured Home Anchoring

Manufactured homes are vulnerable to tornado damage if they are not properly anchored down. As a result, a major national effort has been initiated to encourage structural anchoring or “tie down” of manufactured homes. The Michigan Manufactured Housing Commission Administrative Rules (R 125.1602, Subsection 5) require new manufactured home installations in floodplains to be structurally anchored to a foundation. Through this requirement, the possibility of damage from wind is minimized. Although this will not protect a manufactured home from a direct hit by a tornado, it certainly will help prevent rollovers in most high-wind situations. Unfortunately, structures outside designated floodplains do not have to comply with the anchoring provision, although many owners choose to comply voluntarily. It should also be noted that local communities have the option of adopting an ordinance that requires anchoring of manufactured home installations located outside a designated floodplain. State anchoring system standards are outlined in Administrative Rules R 125.1605 through R 125.1608.

### FEMA Safe Room Benefit-Cost Calculator

An advanced way for a community to analyze the tornado risk for various structures in its part of the state would be to make use of FEMA's 2000 computer model, "Benefit Cost Analysis of Hazard Mitigation Projects: Tornado and Hurricane Shelter Model." This program takes into consideration building information such as area, length, width, and location in the state, to determine whether or not a mitigation project involving reinforced "safe rooms" will provide adequate protection during a tornado for building occupants. Although this program does not specify exact risk of tornado damage for each community, it does provide an approximating regional model to follow for communities considering building tornado "safe rooms" to mitigate tornado deaths and injuries. If your community wants to know more about the feasibility of the "safe rooms," the model is available through the MSP/EMHSD office. Important Note: Only counties with greater tornado risks should inquire about the FEMA computer model, as the model does not work well for counties with very few tornado occurrences. Additionally, FEMA provides a disclaimer on the model that states that the results from the benefit-cost analysis are not conclusive or positively cost-effective—and that modeled projects are NOT guaranteed for potential government grants. For more information about safe rooms, refer to <http://www.fema.gov/safe-rooms>.

### Electrical Infrastructure Reliability

One of the major problems associated with the severe winds from tornadoes and thunderstorms is the loss of electric power caused by trees falling on power lines. Michigan has had numerous widespread and severe electrical power outages caused by severe wind and other weather events. Several of those outages have resulted in upwards of 500,000 electrical customers (more than 5% of the State's population) being without power for several hours to several days at a time. Wind-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. Detroit Edison, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by tornadoes, severe straight-line winds, and other hazards. Typically, these programs focus on trimming trees to prevent encroachment of overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new distribution lines underground. The Michigan Public Service Commission (MPSC) monitors power system reliability to help minimize the scope and duration of power outages.

### Structural Bracing and Wind Engineering

One of the best ways to protect buildings from damage from severe winds associated with thunderstorms, tornadoes, or other high wind events is to install structural bracing and metal connectors (commonly called hurricane clips) at critical points of connection in the frame of the structure. Typically, this involves adding extra gable end bracing at each end of the structure, anchoring the roof rafters to the walls with metal connector straps, and properly anchoring the walls and sill plate to the foundation. This extra bracing helps ensure that the roof stays on the structure, and the structure stays anchored on its foundation. Experience in tornadoes and other high wind events has shown that once the roof begins to peel away from the walls, or the building begins to move off its foundation due to extreme lateral wind forces, major structural damage occurs. If the damage continues unabated, the building can end up being a total loss.

### Urban Forestry and Tree Maintenance Programs

Urban forestry programs can be very effective in minimizing storm damage caused by falling trees or tree branches. In almost every tornado or other severe wind event, falling trees and branches cause power outages and clog public roadways with debris. However, a properly designed, managed and implemented urban forestry program can help keep tree-related damage and impact to a minimum. To be most effective, an urban forestry program should address tree maintenance in a comprehensive manner, from proper tree selection, to proper placement, to proper tree trimming and long-term care.

Every power company in Michigan has a tree trimming program, and numerous local communities have some type of tree maintenance program. The electrical utility tree trimming programs are aimed at preventing encroachment of trees and tree limbs within power line rights-of-way. Typically, professional tree management

companies and utility work crews perform the trimming operations. At the local government level, only a handful of Michigan communities have actual urban forestry departments or agencies. Rather, crews from the public works agency or county road commission perform the bulk of the tree trimming work.

When proper pruning methods are employed, and when the work is done on a regular basis with the aim of reducing potential storm-related damage, these programs can be quite effective. Often, however, tree trimming work is deferred when budgets get tight or other work is deemed a higher priority. When that occurs, the problem usually manifests itself in greater storm-related tree debris management problems down the line. Although nothing will prevent tree damage from a direct tornado strike, a well-planned, well-managed urban forestry program can certainly reduce the scope and magnitude of the post-tornado tree debris problem.

#### ***Mitigation Alternatives for Tornadoes***

- Increased coverage and use of NOAA Weather Radio.
- Public early warning systems and networks.
- Tree trimming and maintenance to prevent limb breakage and safeguard nearby utility lines. (Ideal: Establishment of a community forestry program with a main goal of creating and maintaining a disaster-resistant landscape in public rights-of-way.)
- Buried/protected power and utility lines. (NOTE: Where appropriate. Burial may cause additional problems and costs in case of breakage, due to the increased difficulty in locating and repairing the problem.)
- Using appropriate wind engineering measures and construction techniques (e.g. structural bracing, straps and clips, anchor bolts, laminated or impact-resistant glass, reinforced entry and garage doors, window shutters, waterproof adhesive sealing strips, and interlocking roof shingles) to strengthen public and private structures against severe wind damage.
- Proper anchoring of manufactured homes and exterior structures such as carports and porches.
- Securing loose materials, yard, and patio items indoors or where winds cannot blow them about.
- Construction of concrete safe rooms in homes and shelter areas in mobile home parks, fairgrounds, shopping malls, or other vulnerable public areas.

#### ***Tie-in with Local Hazard Mitigation Planning***

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of tornadoes), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, the information immediately following provides advice regarding the tornado hazard to offer guidance to local planners, officials, and emergency managers. It has been adapted from the February 2003 “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207). For the second type of State-local planning coordination, a section follows that summarizes tornado information as it has been reported in local hazard mitigation plans. For a brief summary of tornado-related information from that section of this plan, it will here be noted that tornadoes were identified as one of the most significant hazards in local hazard mitigation plans for the following counties: Antrim, Arenac, Berrien, Calhoun, Clare, Dickinson, Eaton, Genesee, Gratiot, Hillsdale, Huron, Ingham, Jackson, Kent, Livingston, Mackinac, Macomb, Mecosta, Midland, Monroe, Montcalm, Oakland, Osceola, Ottawa, Saginaw, Van Buren, Washtenaw, and Wayne.

# **Tornado History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013**

(The Lower Peninsula regions are ordered by “tiers” from south to north, west to east)

Please refer to the Michigan Profile Map section for an explanation of regional divisions

<b>COUNTY or area</b>	<b>Tornado Events</b>	<b>Days with Tornadoes</b>	<b>Tot. property damage</b>	<b>Tot. crop damage</b>	<b>Injuries</b>	<b>Deaths</b>
Washtenaw	5	5	\$12,595,000			
Wayne	3	3	\$90,750,000		90	
.Livingston	8	7	\$10,220,000		3	
Oakland	6	6	\$6,917,000			1
Macomb	4	3	\$30,800,000		6	
<b>5 Co Metro region</b>	<b>5.2 avg.</b>	<b>4.8 avg.</b>	<b>\$151,282,000</b>		<b>99</b>	<b>1</b>
Berrien	7	6	\$2,110,000			
Cass	6	5	\$5,900,000			
St. Joseph	6	4	\$822,200		1	
Branch	2	2	\$50,000			
Hillsdale	3	3	\$351,000			
Lenawee	4	4	\$580,000			
Monroe	7	6	\$60,203,000		11	
.Van Buren	4	3	\$110,000	\$10,000		
Kalamazoo	7	6	\$690,500	\$142,000		
Calhoun	4	4	\$3,200,000	\$275,000		
Jackson	2	2	\$700,000	\$50,000		
.Allegan	7	7	\$1,602,000			
Barry	2	2	\$300,000			
Eaton	8	8	\$50,357,000	\$225,000	6	
Ingham	7	7	\$20,850,000	\$200,000	2	2
.Ottawa	3	3	\$250,000	\$10,000		
Kent	7	4	\$570,000	\$30,000		
Ionia	2	2	\$110,000	\$55,000		
Clinton	2	2	\$450,000	\$150,000		
Shiawassee	9	7	\$655,000		1	
Genesee	18	10	\$18,510,000		2	1
Lapeer	9	9	\$1,880,000			
St. Clair	7	7	\$895,000		4	1
.Muskegon	3	3	\$50,000			
Montcalm	2	2	\$152,000	\$25,000		
Gratiot	5	3	\$675,000	\$29,000	1	
Saginaw	13	9	\$6,308,000	\$5,500		
Tuscola	8	7	\$1,060,000		1	
Sanilac	5	5	\$445,000			
.Mecosta	1	1	\$1,200,000		12	
Isabella	5	5	\$715,000	\$10,000	1	
Midland	3	3	\$225,000			
Bay	4	4	\$170,000			
Huron	5	5	\$415,000		1	
<b>34 Co S Lower Pen</b>	<b>5.5 avg.</b>	<b>4.7 avg.</b>	<b>\$182,560,700</b>	<b>\$1,216,500</b>	<b>43</b>	<b>4</b>

Continued on next page...

**Part 2 of Michigan County Tornado Events table**

.Oceana						
Newaygo	4	4	\$62,000	\$10,000		
.Mason	1	1				
Lake	1	1	\$150,000	\$50,000		
Osceola	5	5	\$512,000	\$100,000	1	
Clare	3	3	\$210,000	\$10,000		
Gladwin	2	2	\$90,000			
Arenac	3	3	\$15,000	\$1,000	1	
.Manistee	1	1	\$15,000			
Wexford	1	1	\$8,000			
Missaukee	1	1				
Roscommon						
Ogemaw	2	2	\$75,000			
Iosco	1	1	\$75,000			
.Benzie						
Grand Traverse						
Kalkaska	3	3	\$1,100,000		1	1
Crawford	4	4	\$60,000			
Oscoda	4	3	\$2,890,000		2	
Alcona	3	3	\$315,000			
.Leelanau	1	1	\$20,000			
Antrim	2	2	\$4,000			
Otsego	1	1	\$11,000			
Montmorency	3	3	\$210,000			
Alpena	4	3	\$491,000			
.Charlevoix	1	1				
Emmet	1	1				
Cheboygan	2	2	\$30,000			
Presque Isle	2	2				
<b>29 Co N Lower Pn</b>	<b>1.9 avg.</b>	<b>1.8 avg.</b>	<b>\$6,343,000</b>	<b>\$172,000</b>	<b>5</b>	<b>1</b>
Gogebic	1	1	\$25,000			
Iron	1	1	\$15,000			
Ontonagon	1	1	\$20,000			
Houghton						
Keweenaw	1	1				
Baraga						
.Marquette	4	4	\$10,000	\$5,000		
Dickinson	6	3	\$7,013,000	\$120,000		
Menominee	2	2	\$25,000			
Delta	4	4	\$38,000			
Schoolcraft						
Alger	1	1				
.Luce	1	1				
Mackinac	1	1				
Chippewa	1	1	\$200,000			
<b>15 Co Upp.Pen</b>	<b>1.6 avg.</b>	<b>1.5 avg.</b>	<b>\$7,346,000</b>	<b>\$125,000</b>		
<b>MICHIGAN TOTAL</b>	<b>292</b>	<b>127</b>	<b>\$347,332,000</b>	<b>\$1,512,000</b>	<b>147</b>	<b>6</b>

### Number of Tornadoes in Michigan, by County: 1950-2009

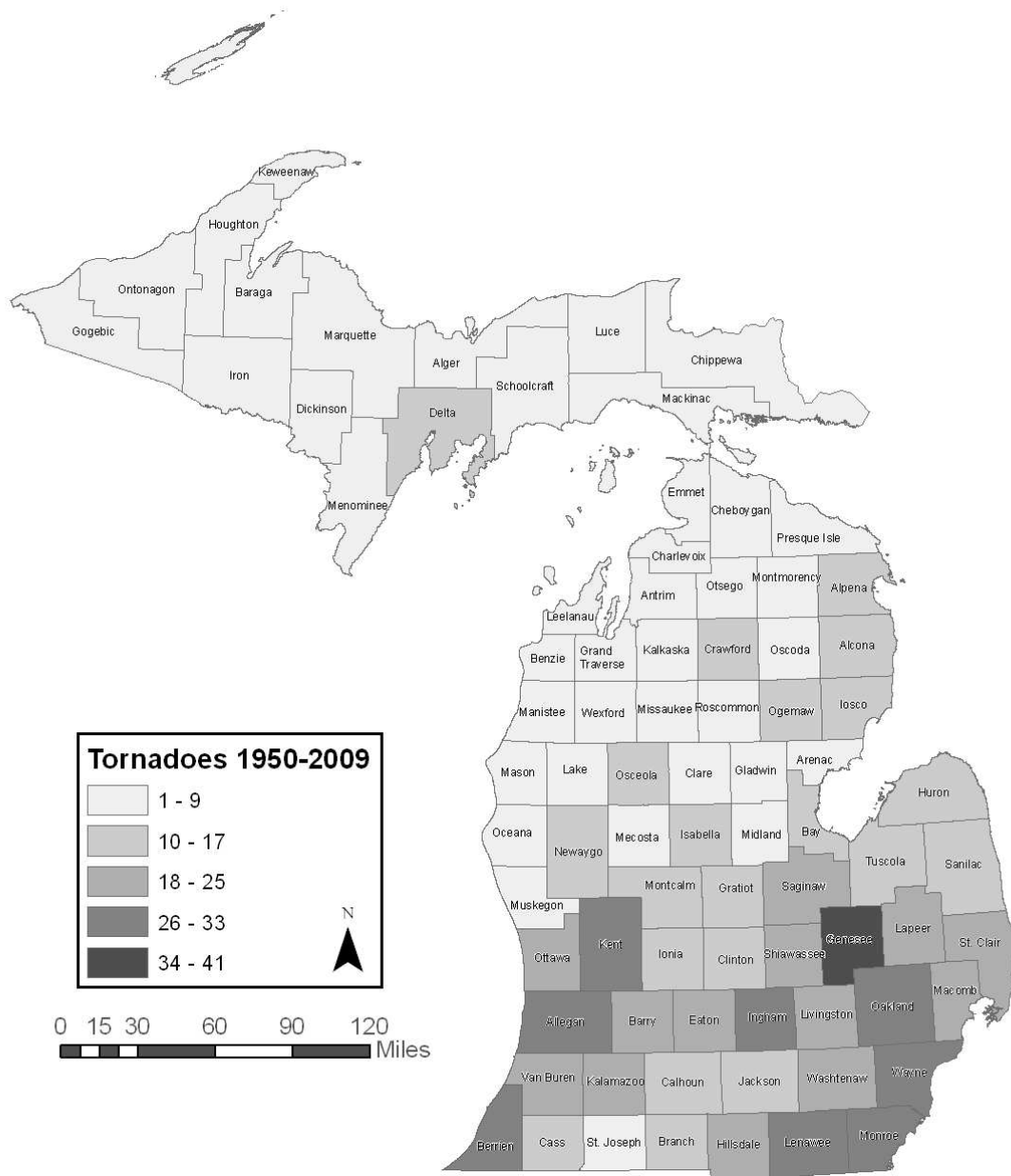
County (A-K)	Tornadoes: 1950-2009	County (L-Z)	Tornadoes: 1950-2009
Alcona	11	Lake	2
Alger	6	Lapeer	20
Allegan	26	Leelanau	3
Alpena	14	Lenawee	31
Antrim	9	Livingston	24
Arenac	7	Luce	2
Baraga	2	Mackinac	5
Barry	18	Macomb	18
Bay	12	Manistee	2
Benzie	4	Marquette	6
Berrien	28	Mason	5
Branch	15	Mecosta	9
Calhoun	15	Menominee	7
Cass	14	Midland	8
Charlevoix	4	Missaukee	8
Cheboygan	6	Monroe	28
Chippewa	6	Montcalm	11
Clare	8	Montmorency	6
Clinton	17	Muskegon	7
Crawford	10	Newaygo	12
Delta	11	Oakland	31
Dickinson	7	Oceana	5
Eaton	25	Ogemaw	14
Emmet	5	Ontonagon	2
Genesee	41	Osceola	16
Gladwin	9	Oscoda	5
Gogebic	3	Otsego	3
Gd. Traverse	4	Ottawa	18
Gratiot	12	Presque Isle	6
Hillsdale	23	Roscommon	8
Houghton	1	Saginaw	21
Huron	12	Sanilac	14
Ingham	27	Schoolcraft	3
Ionia	17	Shiawassee	25
Iosco	11	St. Clair	20
Iron	5	St. Joseph	9
Isabella	13	Tuscola	17
Jackson	17	Van Buren	18
Kalamazoo	25	Washtenaw	24
Kalkaska	7	Wayne	28
Kent	31	Wexford	7
Keweenaw	2	<b>STATEWIDE:</b>	<b>923</b>

IMPORTANT NOTE: Tornadoes that crossed county lines are counted more than once in this table.

Therefore, the statewide total is less than the sum of the individual county totals.

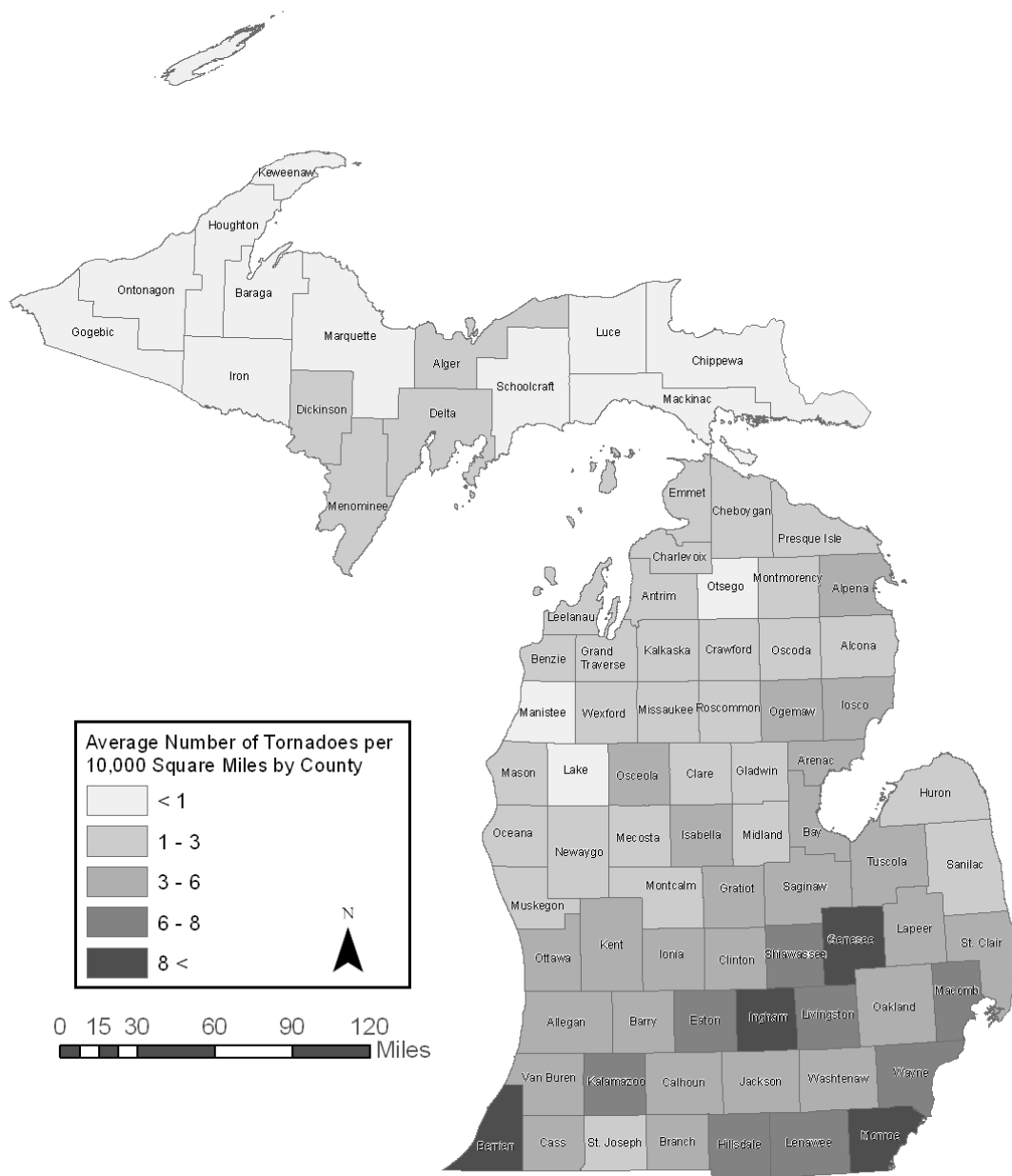
Source: National Weather Service

## Historic Tornadoes per County



Produced by:  
Michigan State Police  
Emergency Management and Homeland Security Division  
December 2010

## Tornadoes 1950 - 2009



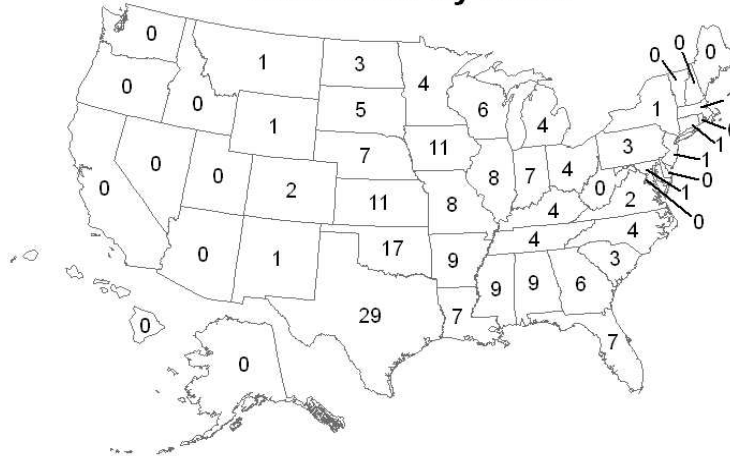
Produced by:  
Michigan State Police  
Emergency Management and Homeland Security Division  
December 2010

## Tornado Frequency, by land area (per 10,000 square miles)

## Comparative National Tornado Statistics

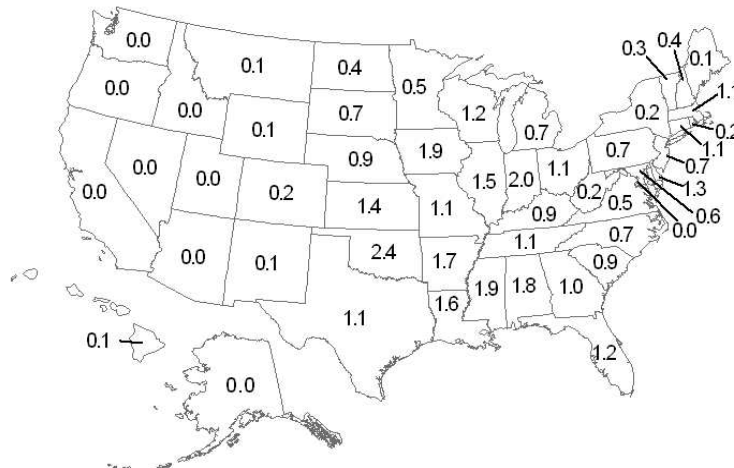
Source: National Weather Service

### Annual Average Number of Strong-Violent (F2-F5) Tornadoes by State



\* These maps use data for the years 1950 to 2009 for the State of Michigan only, but the rest of the states show data only for the years 1950 to 1995. Although updated national maps were not available from the National Weather Service for use in this plan, new information for Michigan was readily provided upon request, and these maps were then revised by MSP/EMHSD staff to reflect this new data

### Average Annual Number of Strong-Violent (F2-F5) Tornadoes per 10,000 Square Miles by State



Michigan State Police  
Emergency Management & Homeland Security Division  
January 2011

# Extreme Temperatures

*Prolonged periods of very high or very low temperatures, often accompanied by other extreme meteorological conditions.*

## ***Hazard Description***

Temperature extremes are broken down into two categories: extreme heat and extreme cold. Both extremes can last for weeks, without any advance warning and in the middle of a seemingly normal weather pattern. Additionally, both extreme heat and extreme cold can cause loss of life to vulnerable populations, damage to infrastructure, and disruptions to schools and businesses.

Extreme cold is primarily associated with the wintery months of November through March and categorized by temperatures plunging near or below 0°F. Extreme heat occurs mainly during the summer months of June, July, and August and is marked by temperatures above 90°F.

Although all counties in Michigan are susceptible to harsh subfreezing temperatures, counties in the North Central and Upper Peninsula of the state typically have more annual days of extreme cold than the southern portions of Michigan. Periods of extreme cold are risky for those in both rural and in urban areas. Frostbite and hypothermia is common in rural areas where people are trapped outdoors and do not adjust properly to the temperatures. Even indoors, hypothermia is a concern for individuals living in inadequately heated apartments or rooms. Loss of life can occur with either of these situations. Damage to buildings and pipelines can also occur in bitter cold conditions, resulting in expensive repairs and potential days of business and school shutdowns.

Counties in the southern half of the state have the highest frequency of days exhibiting extreme heat. Urban areas are especially prone to days with soaring temperatures, with concrete and asphalt surfaces reflecting sunlight, air pollutants trapping heat, and lessened circulation of air through densely-developed areas. Individuals working outdoors, the elderly, and children need to be accounted for during oppressively sizzling conditions, as they are most at risk for heat exhaustion, and fatal heat stroke. Scorching weather also puts a strain on the energy demands for an area, as air conditioning becomes a necessity for vulnerable populations. Possible shutdowns of schools, colleges, and industries can occur during these times.

Prolonged periods of extreme temperatures, whether extreme summer heat or extreme winter cold, can pose severe and life-threatening problems for Michigan's citizens. Although they differ in their initiating conditions, the two hazards share a commonality in that they both tend to have a special impact on the most vulnerable segments of the population—the elderly, young children and infants, impoverished individuals, and persons who are in poor health. Due to their different characteristics, extreme summer heat and extreme winter cold hazards will mostly be discussed separately in this section. For both types of temperature extremes, however, a longer hot or cold spell makes the temperature effects much more severe on vulnerable populations—a longer duration tends to produce more severe effects.

## ***Hazard Analysis***

**Extreme Summer Heat** is characterized by a combination of very high temperatures and humid conditions. When persisting over a long period of time, this phenomenon is commonly called a heat wave. The major threats of extreme summer heat are heat exhaustion and heatstroke (a major medical emergency). **Heat exhaustion** is a less severe condition than heatstroke, but it causes problems involving dizziness, weakness and fatigue. Heat exhaustion is often the result of fluid imbalance due to increased perspiration in response to the intense heat. Treatment generally consists of restoring fluids and staying indoors in a cooler environment until the body returns to normal. If heat exhaustion is not addressed and treated, it can advance to heatstroke, so medical attention should be sought immediately.

**Heatstroke** symptoms include a high body temperature (it can be 106 degrees or higher), dry skin, inadequate perspiration, paleness or reddening, confusion or irritability, and seizures. The victim may become delirious, stuporous, unconscious, or even comatose. Cooling is essential to preventing permanent neurological damage or death. Other, less serious risks associated with extreme summer heat are often exercise-related and include **heat cramps** (an imbalance of fluids that occurs when people unaccustomed to heat exercise outdoors) and **heat syncope** (a loss of consciousness by persons not acclimated to hot weather). Periods of hot weather also entail risks of dehydration, even for those who are not engaged in demanding physical activities. Non-caffeinated fluids should be consumed to maintain adequate hydration.

A useful set of general principles to recognize is that evaporation is a cooling mechanism for our bodies. Evaporation of moisture (i.e. perspiration) doesn't occur as rapidly when the surrounding air already has a relatively high moisture content (humidity). Thus, humidity inhibits evaporation and produces a feeling of greater heat, while winds assist the evaporation of perspiration from skin and thus tend to produce a feeling of greater coolness. It can therefore be difficult for the body to precisely gauge actual outdoor temperatures—it rather senses the potential for heat gain or loss. A period of extreme heat is more debilitating when the air humidity is high, and a period of extreme cold is similarly more dangerous when coupled with strong winds. For these reasons, temperature alone is usually only a limited indicator of the weather's likely threat to human health, and additional factors should also be considered. The additional factors of humidity and wind speed have provided the basis for two additional means of describing the extent of extreme temperatures' impact—the **Heat Index** (HI) and the **Wind Chill Temperature Index** (WCT).

The following tables indicate the way that temperature, humidity, and wind speed probably feels to the human body, and suggest the types of temperature effects relevant to Michigan's climate. Although some of the resulting heat numbers may at first seem outrageous to describe Michigan temperatures, some of the extremes are actually comparable to what is felt in a sauna, which is often set at more than 140 degrees. Like saunas, such heat should not be felt by the body for more than brief periods of time, and since one of the body's cooling reactions is to increase the rate of blood circulation, this also adds to the burden placed on the heart muscle, and can be too much strain for some persons to bear.

HEAT INDEX	Actual Temperature (degrees Fahrenheit)									
Rel. Humidity	90	92	94	96	98	100	102	104	106	108
40%	91	94	97	101	105	109	114	119	124	130
45%	92	96	100	104	109	114	119	124	130	137
50%	95	99	103	108	113	118	124	131	137	144
55%	97	101	106	112	117	124	130	137	145	
60%	100	105	110	116	123	129	137	145		
65%	103	108	114	121	128	136	144			
70%	106	112	119	126	134	143				
75%	109	116	124	132	141					
80%	113	121	129	138						
85%	117	126	135	145						
90%	122	131	141							
95%	127	137								

Source: formulas obtained from the National Climatic Data Center

TECHNICAL NOTE: The two indices can also be summarized by the following mathematical formulas, in which T means temperature (in degrees Fahrenheit), H means relative humidity (%), W means wind speed (in miles per hour), and E denotes a shorthand for scientific notation (times 10 raised to the power of the number that follows the E):

$$HI = -42.38 + 2.049T + 10.14H - 0.2248HT - (6.838E-3)T^2 - (5.482E-2)H^2 + (1.229E-3)HT^2 + (8.528E-4)H^2T - (1.99E-6)H^2T^2$$

$$WCT = 35.74 + 0.6215T - 35.75(W^{0.16}) + 0.4275T(W^{0.16})$$

WIND CHILL	Actual Temperature (degrees Fahrenheit)									
Wind speed (mph)	40	30	20	10	0	-10	-20	-30	-40	-50
5	36	25	13	1	-11	-22	-34	-46	-57	-69
10	34	21	9	-4	-16	-28	-41	-53	-66	-78
15	32	19	6	-7	-19	-32	-45	-58	-71	-83
20	30	17	4	-9	-22	-35	-48	-61	-74	-88
25	29	16	3	-11	-24	-37	-51	-64	-78	-91
30	28	15	1	-12	-26	-39	-53	-67	-80	-94
35	28	14	0	-14	-27	-41	-55	-69	-82	-96
40	27	13	-1	-15	-29	-43	-57	-71	-84	-98
45	26	12	-2	-16	-30	-44	-58	-72	-86	-100
50	26	12	-3	-17	-31	-45	-60	-74	-88	-102
55	25	11	-3	-18	-32	-46	-61	-75	-89	-104
60	25	10	-4	-19	-33	-48	-62	-76	-91	-105

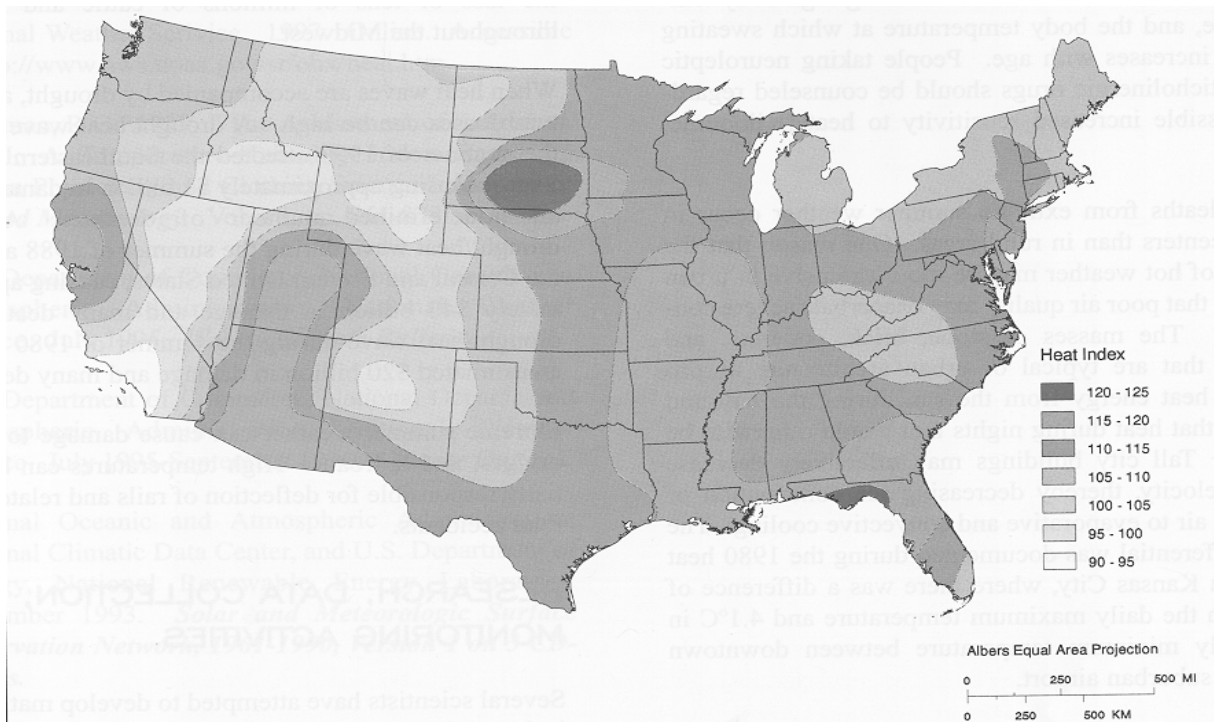
Other tables and calculators can be found online, such as the tables for a heat index at <http://www.ncdc.noaa.gov/oa/climate/conversion/heatindexchart.html>, or the tables and calculator for wind chill at <http://www.nws.noaa.gov/om/windchill/>.

Although these indices involve a fairly straightforward means of expressing the “feel” of the weather in terms of a temperature equivalent, conditions for each individual will still vary with the duration and type of weather exposure, personal health, extent of acclimation, and the type of clothing worn. For example, exposure to full sunshine can increase heat index values by up to 15%. Also, cooler air holds less moisture, and dryer air readily allows the cooling evaporation of perspiration from skin. In other words, the heat index and wind chill index only involve a consideration of two important factors, but they are still more useful than a consideration of temperature alone. The Heat Index table assumes shady conditions with a light wind. Actual indoor conditions may vary, trapping heat and/or humidity in some locations and making them potentially much more dangerous. Prolonged exposure, physical activity, and age all tend to increase the risks associated with heat. Conditions that might cause heat cramps in a teenager could be experienced as heat exhaustion by a middle-aged person, and as heat stroke by a senior citizen. Young infants, however, are also vulnerable to heat effects.

Extremely high numbers are not shown in the table, since there are limits on the extent to which both humidity and heat would be experienced as a part of Michigan’s weather (shown on the map below). However, the following guidelines are recommended, to make better use of the raw numbers:

<u>Heat Index above 130 degrees:</u>
<b>Extreme Danger</b> (Heat stroke or sunstroke is highly likely with prolonged exposure and/or physical activity)
<u>Heat Index in the 105 to 129 degree range:</u>
<b>Danger</b> (Sunstroke, muscle cramps, heat exhaustion is likely with prolonged exposure and physical activity)
<u>Heat Index in the 90 to 104 degree range:</u>
<b>Extreme Caution</b> (Sunstroke, muscle cramps and/or heat exhaustion possible with prolonged exposure/activity)
<u>Heat Index up through 89 degrees:</u>
<b>Caution</b> (Fatigue possible with prolonged exposure and/or physical activity)

## Severity and Extent of Extreme Summer Heat in the United States



Source: U.S. Department of Commerce; *Multi-Hazard Identification and Risk Assessment*, 1999, FEMA

**Extreme Heat History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013**

(The Lower Peninsula regions are ordered by “tiers” from south to north, west to east)

Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	Extreme Heat Events	Days with Extreme Heat	Injuries	Deaths
Washtenaw	12	12	17	
Wayne	14	14	541	3
.Livingston	12	12	4	
Oakland	15	15	194	5
Macomb	13	13	60	
<b>5 Co Metro region</b>	<b>13 avg.</b>	<b>13 avg.</b>	<b>816</b>	<b>8</b>
Berrien				
Cass				
St. Joseph				
Branch				
Hillsdale				
Lenawee	12	12	2	
Monroe	12	12	2	
.Van Buren				
Kalamazoo				
Calhoun				
Jackson				
.Allegan				
Barry				
Eaton				
Ingham				
.Ottawa				
Kent				
Ionia				
Clinton				
Shiawassee	11	11	5	
Genesee	9	9	23	
Lapeer	11	11	1	
St. Clair	11	11	7	
.Muskegon				
Montcalm				
Gratiot				
Saginaw	11	11	19	
Tuscola	11	11	1	
Sanilac	10	10	1	
.Mecosta				
Isabella				
Midland	11	11	3	
Bay	11	11	1	
Huron	10	10	1	
<b>34 Co S Lower Pen</b>	<b>3.8 avg.</b>	<b>3.8 avg.</b>	<b>66</b>	

Continued on next page...

**Part 2 of Michigan County Extreme Heat History Table**

.Oceana				
Newaygo				
.Mason				
Lake				
Osceola				
Clare				
Gladwin	1	1		
Arenac	1	1		
.Manistee	1	1		
Wexford	1	1		
Missaukee	1	1		
Roscommon	1	1		
Ogemaw	1	1		
Iosco	1	1		
.Benzie	1	1		
Grand Traverse	1	1		
Kalkaska	1	1		
Crawford	1	1		
Oscoda	1	1		
Alcona	1	1		
.Leelanau	1	1		
Antrim	1	1		
Otsego	1	1		
Montmorency	1	1		
Alpena	1	1		
.Charlevoix	1	1		
Emmet	1	1		
Cheboygan	1	1		
Presque Isle	1	1		
<b>29 Co N Lower Pn</b>	<b>0.8 avg.</b>	<b>0.8 avg.</b>		
Gogebic	1	1		
Iron	1	1		
Ontonagon	1	1		
Houghton				
Keweenaw	1	1		
Baraga	1	1		
.Marquette	1	1		
Dickinson	1	1		
Menominee	1	1		
Delta				
Schoolcraft				
Alger	1	1		
.Luce				
Mackinac	1	1		
Chippewa	1	1		
<b>15 Co Upp.Pen</b>	<b>0.7 avg.</b>	<b>0.7 avg.</b>		
<b>MICHIGAN TOT.</b>	<b>234</b>	<b>18</b>	<b>882</b>	<b>8</b>

In Michigan, heat advisories will tend to be announced when the heat index is calculated to exceed 105 degrees in an area for a period of at least 3 hours in duration. It should be noted, however, that the temperature inside of vehicles without air conditioning can be dozens of degrees hotter than the outdoor temperature—an outdoor temperature might be “only” 100 degrees Fahrenheit, but people may then get into a car that exceeds 130 degrees. People vary in the conditions in which they operate (and in their capacity to tolerate extreme temperatures), and can find themselves in circumstances that threaten their health even if no official temperature advisory has been issued.

Heat waves tend to have stagnant atmospheric conditions that trap pollutants in urban areas and thus compound the health effects faced by urban residents. Because the combined effects of high temperatures, high humidity, and trapped pollution are focused more intensely in urban centers, heatstroke and heat exhaustion are a greater problem in sizeable cities than in suburban or rural areas. Nationwide, approximately 135 deaths per year are attributable to extreme heat (a total of 3,311 over the 24 year period from 1986 to 2009, according to <http://www.nws.noaa.gov/om/hazstats/images/70-years.pdf>). Extreme summer heat is also hazardous to livestock and agricultural crops, and it can cause water shortages, exacerbate fire hazards, and prompt excessive demands for energy. Roads, bridges, railroad tracks and other infrastructure are susceptible to damage from extreme heat (due to the effects of thermal expansion of materials). Scorching weather also puts a strain on the energy demands for an area, as the use of air conditioning increases greatly. Possible shutdowns of schools, colleges, and industries can occur during these times.

Air conditioning is probably the most effective measure for mitigating the effects of extreme summer heat on people. Unfortunately, many of those most vulnerable to this hazard do not live or work in air-conditioned environments, especially in major urban centers where the vulnerability is highest. The use of fans to move air may help some persons feel more comfortable, but when the temperature reaches the high 90s, fans will not prevent heat-related illness. Bathing with cool water is more effective, but moving to a cooler environment (a basement or air-conditioned location) is most effective—even if only for a few hours per day.

To mitigate the extreme heat of summer, communities should have a contingency plan in place to protect those people who are most vulnerable to the heat. These contingency plans should include: setting up “cooling stations” where people can go to get out of the heat; a hierarchy of closings for industries, businesses, and schools during shutdown periods; and a means of explaining the dangers of heat conditions, such as pamphlets and local broadcast and print media. Monitoring of dangerous conditions can also be done through the National Weather Service website. A risk assessment should calculate the likelihood of such incidents and the number of days of extreme temperatures likely to be experienced in your community each year. It should also take account of past losses and harm caused by such events, and determine who or what is still vulnerable to such conditions today.

Heat waves severe enough to threaten health do not occur every year, and several relatively mild summers may intervene between major heat waves. The problem is complicated by the fact that long-term weather forecasts cannot reliably predict prolonged periods of extreme summer heat. Short-term forecasts of hot weather are more accurate, but often leave little time for mobilizing to effectively combat the hazard. Nevertheless, planning and preparedness activities can occur to mitigate the effects of this weather hazard.

Because of its geographic location in relation to the Great Lakes, Michigan is somewhat less susceptible to prolonged periods of extreme hot temperatures than are many other states. However, the Upper Midwest, in which Michigan is located, is definitely vulnerable to extreme temperature events. As a result, Michigan communities (and particularly urban centers) must always be prepared to respond to heat events in an organized, coordinated and expedient manner. Extreme summer heat poses the greatest danger to urban residents—especially the elderly, children, outdoor laborers, people with poor health, and people residing in homes without air conditioning. Michigan’s urban communities must address extreme summer heat in their emergency preparedness efforts. Human service agencies, voluntary organizations, health departments, medical and health care facilities, and schools may have a role in response to a heat wave. The Michigan Department of Community

Health, together with local health departments, medical and health care facilities, may have to establish specialized medical surge facilities to assist in the care of a large number of persons who may be affected in such events. In addition, the local media could be tapped to assist in information dissemination and community outreach efforts.

In an average year, Michigan has many days above 90° Fahrenheit. MDCH and NWS estimate about 5 deaths per year, on average, due to extreme heat. Although larger cities have been noted as having more risk from extreme heat, it should also be noted that residents in isolated rural locations may have trouble accessing air-conditioned places, or reaching designated cooling shelters. Such access may be easier for urban residents.

**Extreme Winter Cold** periods can, like heat waves, result in a significant number of temperature-related deaths. Each year in the United States, approximately 700 persons die as a result of severe cold temperature-related causes. This is substantially higher than the average of 175 heat-related deaths each year. It should be noted that a significant number of cold-related deaths are not the direct result of “freezing” conditions. Rather, many deaths are the result of illnesses and diseases that are negatively impacted by severe cold weather, such as stroke, heart disease and pneumonia. It could convincingly be argued that, were it not for the extreme cold temperatures, death would not have occurred at the time that it did due to the illness or disease alone. There are, in various parts of Michigan, an average of between 3 and 50 (or more) days per year at or below 0° Fahrenheit. Michigan also tends to have between 90 and 180 (or more) days per year in which the temperature is below the freezing point.

**Hypothermia** (the unintentional lowering of core body temperature), and **frostbite** (damage from tissue being frozen) are probably the two conditions most closely associated with cold temperature-related injury and death. Hypothermia is usually the result of over-exposure to the cold, and is generally thought to be clinically significant when core body temperature reaches 95 degrees or less. As body temperature drops, the victim may slip in and out of consciousness, and appear confused or disoriented. Treatment normally involves warming the victim (preferably performed by trained medical personnel) but frostbitten areas should not be rubbed. Although frostbite damage itself rarely results in death (which may occur due to hypothermia instead), in extreme cases it can result in the amputation of the affected body tissue.

Periods of extreme cold are risky for those in both rural and in urban areas. Frostbite and hypothermia is common in rural areas where people are trapped outdoors and do not adjust properly to the temperatures. Even indoors, hypothermia is a concern for individuals living in inadequately heated apartments or rooms. Loss of life can occur with either of these situations. Damage to buildings and pipelines can also occur in bitter cold conditions, resulting in expensive repairs and potential days of business and school shutdowns.

To mitigate the effects of the unfavorable cold temperatures, communities should make sure that housing codes are appropriate and that adequate furnaces are in place in apartment dwellings. Inspections of vulnerable and outdated infrastructure should be made in the fall season, before winter sets in. In addition, proper insulation of piped areas can prevent water main breaks.

In the wind chill chart, extremely low apparent temperatures can also be associated with an amount of exposure time that it takes to cause frostbite. Cells of the table that have darker shadings denote wind chill temperatures that can produce frostbite in 10 minutes or less. Cells with lighter shadings are associated with frostbite times of 30 minutes or less. Unshaded cells in the table should require longer exposure times to cause frostbite. Again, the chart displays only two factors that contribute heavily to risk, but risk can be increased for an individual in particular circumstances. For example, people should be aware that the drier air (common to winter weather) also allows a more rapid drop in temperature than is the case with warm summer air. As a cold front moves in, or as daytime high temperatures for the day change to nighttime low temperatures, the corresponding drop in temperature can be much greater when the humidity is low. Persons who are outdoors can rapidly find themselves in danger of hypothermia.

**Extreme Cold History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013**

(The Lower Peninsula regions are ordered by “tiers” from south to north, west to east)

Please refer to the Michigan Profile Map section for an explanation of regional divisions

<b>COUNTY or area</b>	<b>Extreme Cold Events</b>	<b>Days with Extreme Cold</b>	<b>Tot. property damage</b>	<b>Tot. crop damage</b>	<b>Injuries</b>	<b>Deaths</b>
Washtenaw	9	9	\$500,000		10	
Wayne	16	15	\$275,000		34	9
.Livingston	7	7	\$25,000		10	
Oakland	8	8	\$25,000		14	4
Macomb	9	9	\$25,000		11	3
<b>5 Co Metro region</b>	<b>9.8 avg.</b>	<b>9.6 avg.</b>	<b>\$850,000</b>		<b>79</b>	<b>16</b>
Berrien						
Cass						
St. Joseph						
Branch						
Hillsdale						
Lenawee	9	9	\$1,025,000		10	
Monroe	9	9	\$25,000		10	
.Van Buren						
Kalamazoo						
Calhoun						
Jackson						
.Allegan						
Barry						
Eaton						
Ingham						
.Ottawa						
Kent	1	1	\$150,000			
Ionia						
Clinton						
Shiawassee	6	6	\$25,000		10	
Genesee	7	7	\$25,000		11	
Lapeer	6	6	\$25,000		10	
St. Clair	6	6	\$25,000		10	
.Muskegon						
Montcalm	1	1		\$100,000		
Gratiot						
Saginaw	7	7	\$525,000		10	
Tuscola	6	6	\$25,000		10	
Sanilac	7	7	\$25,000		10	1
.Mecosta						
Isabella						
Midland	6	6	\$25,000		10	
Bay	7	7	\$25,000		10	2
Huron	6	6	\$25,000		10	
<b>34 Co S Lower Pen</b>	<b>84 avg.</b>	<b>84 avg.</b>	<b>\$1,950,000</b>	<b>\$100,000</b>	<b>121</b>	<b>3</b>

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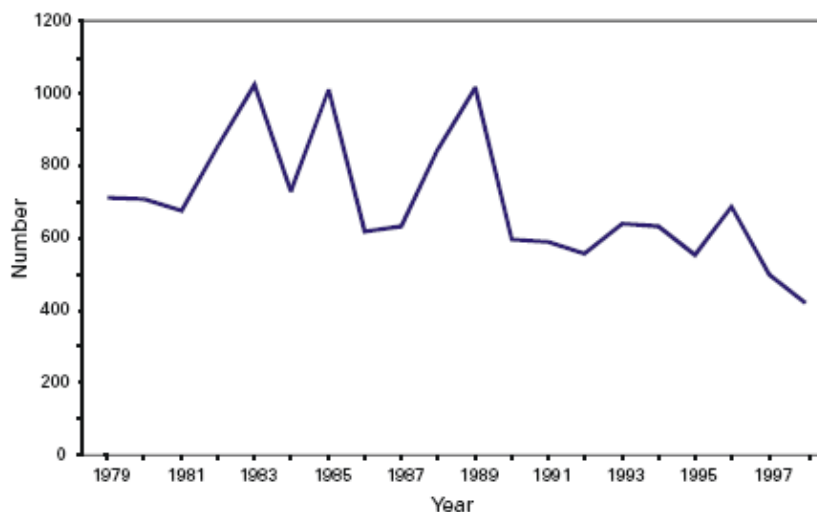
**Part 2 of Michigan County Extreme Cold History Table**

.Oceana	1	1		\$2,000,000		
Newaygo						
.Mason						
Lake						
Osceola						
Clare						
Gladwin	1	1				
Arenac	1	1				
.Manistee	1	1				
Wexford	1	1				
Missaukee	1	1				
Roscommon	1	1				
Ogemaw	1	1				
Iosco	1	1				
.Benzie	1	1				
Grand Traverse	2	1				
Kalkaska	2	1				
Crawford	1	1				
Oscoda	1	1				
Alcona	1	1				
.Leelanau	2	2				1
Antrim	1	1				
Otsego	1	1				
Montmorency	1	1				
Alpena	1	1				
.Charlevoix	1	1				
Emmet	1	1				
Cheboygan	1	1				
Presque Isle	1	1				
<b>29 Co N Lower Pn</b>	<b>0.93 avg</b>	<b>0.86 avg.</b>		<b>\$2,000,000</b>		<b>1</b>
Gogebic	19	19				
Iron	18	18				1
Ontonagon	13	13				
Houghton						
Keweenaw	6	6				
Baraga	16	16				
.Marquette	16	16				
Dickinson	17	17				
Menominee	13	13				
Delta	11	11				
Schoolcraft	10	10				
Alger	5	5				
.Luce	3	3				
Mackinac	1	1				
Chippewa	2	2				
<b>15 Co Upp.Pen</b>	<b>10 avg.</b>	<b>10 avg.</b>				<b>1</b>
<b>MICHIGAN TOTAL</b>	<b>325</b>	<b>56</b>	<b>\$2,800,000</b>	<b>\$2,100,000</b>	<b>200</b>	<b>21</b>

Hypothermia usually occurs in one of two sets of circumstances. One situation involves hypothermia associated with prolonged exposure to cold while participating in outdoor sports such as skiing, hiking or camping. Most victims of this form of hypothermia tend to be young, generally healthy individuals who may lack experience in dealing with extreme cold temperatures. The second situation involves a particularly vulnerable person who is subjected to only a moderate, indoor cold stress. A common example would be that of an elderly person living in an inadequately heated home. In such circumstances, hypothermia may not occur until days or perhaps weeks after the cold stress begins. Isolated rural locations may involve difficulties in reaching a heated space, or a designated warming shelter.

Deaths due to extreme winter cold are often not associated with a particular weather event. Rather, they are the result of a one-time over-exposure to severe cold weather (a hiker lost in the woods, or car failure in a rural area), or more commonly from continuous exposure to moderate cold temperatures by vulnerable persons (such as the elderly). In some cases, hypothermia deaths can be linked to severe winter weather such as snowstorms or blizzards, where the victim is caught unprepared for the extreme cold temperatures. As mentioned earlier, many cold temperature-related deaths involve the exacerbation of an existing, serious medical condition such as heart disease or pneumonia. In Michigan, approximately 70% of weather-related fatalities (about 40 deaths per year) are attributed to exposure to the cold (according to the Michigan Department of Community Health and the National Weather Service). The following 20-year table gives an indicator for the nation as a whole.

### Number of Hypothermia-Related Deaths in U.S.: 1979-1998



Source: CDC Morbidity and Mortality Weekly Report

The special vulnerability of elderly persons to hypothermia has become apparent. Over half of the hundreds who die each year due to cold exposure are 60 years of age or older, even though this age group only represents about 20% of the country's population. This remarkable statistic may be due, in part, to an impaired perception of cold as well as the voluntarily setting of thermostats to relatively low temperatures. In addition, high energy costs and the relative poverty among some elderly people may discourage their setting thermostats high enough to maintain adequate warmth (just as it may cause others to limit their use of fans and air conditioning during summer heat waves). Because many elderly people live alone and do not have regular visitors, the cold conditions may persist for several days or weeks, thus allowing hypothermia to set in.

Babies and very young children are also very vulnerable to hypothermia. In addition, statistics indicate that death due to cold is more frequent among males than females in virtually all age groups. Part of that may be explained by differences in risk factors, and part may be due to different rates of cold exposure between activities performed by different sexes. Cold weather also increases blood viscosity, narrows small blood vessels, and increases blood pressure, all of which increase the risk of cardiovascular problems (e.g. a heart attack).

As explained in the general introduction to the weather hazards section of this plan, there should be no presumption made that temperatures will automatically be higher or lower in a southern or northern part of the state, despite the existence of certain trends and correlations. All parts of Michigan experience temperature extremes that threaten health. In fact, Michigan's two most extreme temperatures on record did not occur either in the extreme north of the Upper Peninsula or at the extreme south of the Lower Peninsula, but rather at locations in between – in the Northern part of the Lower Peninsula. The record low temperature of -51 was measured at Vanderbilt (located in Otsego County) and the record high of 112 was at Mio (located in Oscoda County).

Nevertheless, there is some variation across Michigan in the conditions under which wind chill advisories are issued, since it is the case that the warm season is longer in the southern part of the Lower Peninsula and there is a different phase of that area's population becoming acclimated to each year's winter weather. For southern Michigan, wind chill advisories tend to be issued when the Wind Chill Temperature is within the -15 to -24 range. In northern Michigan and the Upper Peninsula, advisories tend to be issued when the WCT is within the -20 to -29 range. Wind chill warnings tend to be issued when the WCT gets down to -25 or below, in southern Michigan, or when it gets down to -30 or below, in northern Michigan.

Maps on the following two pages illustrate the average number of days above 90 degrees and the average number of days below zero degrees, Fahrenheit. Although they are based on the three decades from 1971 to 2001, they give an excellent indication of the "typical" annual risk and exposure to Michigan summer and winter temperature extremes, for all of Michigan's counties.

A different type of risk indicator is provided in the subsequent table that lists record low and high temperatures for numerous weather stations across Michigan. For convenience, the listings are divided into three regions: the Southern Lower Peninsula, Northern Lower Peninsula, and Upper Peninsula. Note that these records are for specific stations, and do not necessarily represent all-time records for the counties or surrounding localities in that area. They should instead be taken as an indicator of the extremes to which various specific locations have experienced, across the state.

As already noted in the Introduction to the Weather Hazards section of this plan, although it makes sense to think in terms of three general Michigan regions for an analysis of trends and weather patterns, the extreme temperature hazard must be understood to be a significant one in every part of the state. This is true of both summer and winter temperature extremes. In general, however, "seasons" can be defined for these three regions, to denote when there is a serious risk of extreme temperature events. These "seasons" are based upon the historical occurrence of very high temperatures (above 90 degrees) and very low temperatures (near zero degrees, or below) and will here be generally defined:

	<b>Extreme Heat Risk Season</b>	<b>Extreme Cold Risk Season</b>
<b>Southern Lower Peninsula</b>	Early May to late September	Late November to early April
<b>Northern Lower Peninsula</b>	Late May to late September	Early November to April
<b>Upper Peninsula</b>	Late May to early September	Late September to May



Produced by:  
Michigan State Police



Produced by:  
Haryana State Police

### Historic Temperature Records at Various Michigan Locations

<b>Southern Lower Peninsula</b>	<b>Record Low Temperature</b>	<b>Record High Temperature</b>
Adrian (Lenawee County)	-26° (Jan. 20)	108° (July 14 & 24)
Benton Harbor (Berrien County)	-21° (Jan. 12)	104° (June 1, July 21 & 30)
Coldwater (Branch County)	-23° (Jan. 4)	108° (July 24)
Ann Arbor (Washtenaw County)	-23° (Feb. 11)	105° (July 24)
Bloomington (Van Buren Co.)	-23° (Feb. 3)	105° (July 5 & 13)
Detroit (Wayne County)	-24° (Dec. 22)	105° (July 24)
Jackson (Jackson County)	-21° (Feb. 10)	105° (July 14)
Pontiac (Oakland County)	-22° (Feb. 5)	104° (July 6, 8, 16, 24)
Flint (Genesee County)	-25° (Jan. 18)	108° (July 8, 13)
Grand Rapids (Kent County)	-24° (Feb. 13 & 14)	108° (July 13)
Port Huron (St. Clair County)	-19° (Jan. 19)	103° (July 9)
Harbor Beach (Huron County)	-22° (Feb. 9)	105° (July 10)
Big Rapids (Mecosta County)	-36° (Feb. 11)	103° (July 13, 14 & 30)

The counties listed above start with the southernmost tier in Michigan, and proceed generally northward, tier by tier. Big Rapids is situated on the very edge of the southern and northern regions, and its record low fits the northern region.

<b>Northern Lower Peninsula</b>	<b>Record Low Temperature</b>	<b>Record High Temperature</b>
Alpena (Alpena County)	-37° (Feb. 17)	106° (July 13)
East Tawas (Iosco County)	-29° (Feb. 1 & 20)	106° (July 8 & 9)
Gaylord (Otsego County)	-39° (Jan. 6)	101° (July 11 & 30)
Gladwin (Gladwin County)	-39° (Feb. 20)	105° (July 13)
Traverse City	-37° (Feb. 17)	105° (July 7)
<b>Upper Peninsula</b>	<b>Record Low Temperature</b>	<b>Record High Temperature</b>
Hancock (Houghton County)	-30° (Feb. 9 & 10)	102° (July 7)
Ironwood (Gogebic County)	-41° (Jan. 17, Feb. 12)	104° (July 13)
Munising (Alger County)	-33° (Feb. 25)	103° (July 7, 8, 9, Aug. 6)
Sault Ste. Marie (Chippewa Co.)	-37° (Feb. 8 & 10)	98° (July 3, 30, Aug 5, 6)
<b>Statewide all-time records</b>	-51° (Feb. 9) Vanderbilt (Otsego County)	112° (July 13) Mio (Oscoda Co.)

Source: Extreme Michigan Weather, by Paul Gross (2010, University of Michigan Press, Ann Arbor)

These tables show all the record low and high temperatures at various weather stations across Michigan. It can be noted that the majority of record low temperatures occurred in January and February, and the majority of record high temperatures took place in July. This pattern holds true across all of Michigan's regions. It should also be noted that lower-lying areas often experience colder temperatures, since colder air is denser and heavier and thus tends to sink to lower areas. Local variations of that type help to explain why the absolute coldest and hottest temperature extremes ever recorded in Michigan are more extreme than the various records listed for specific weather stations.

The tempering effects of the Great Lakes also help moderate the impact of the severe cold weather normally prevalent in the Midwest during the winter months. Even so, Michigan still endures many days of extremely cold temperatures in an average winter, and prolonged periods of extreme cold are not uncommon during the months of January and February. During those months especially, increased outreach to elderly persons - particularly those living alone - is certainly warranted. In addition, communities should be particularly cognizant of the vulnerability of elderly as well as very young persons when power outages occur due to ice and snowstorms. When outages are expected to last for several hours or more, consideration should be given to opening warming

shelters. Once power is restored, outreach to the elderly may be necessary to ensure that furnaces have been re-started and are working properly.

Extreme cold temperatures are a universal hazard in Michigan. Whereas heat waves tend to impact urban centers more than suburban or rural areas, cold temperatures are an “equal opportunity” killer. Every community in Michigan is vulnerable, regardless of location or size. It must also be noted that many of the agricultural sectors of Michigan are vulnerable to crop losses because of extreme cold events.

#### Impact on the Public

Extreme temperatures can have direct impacts on personal health and productivity, which may collectively lead to reductions in economic activity and travel (e.g. tourism, shopping). Extreme temperature events tend to cause greater energy use, which can involve not only higher energy costs but can also result in infrastructure failures due to limitations in the capacity of the utility system. About 900 annual deaths nationwide have been attributed to extreme temperatures (mostly from extreme cold, involved in about 700 deaths), ranking this hazard as the second leading cause of fatalities (behind structural fires).

#### Impact on Public Confidence in State Governance

Questions may arise about the amount of utility assistance, provision/promotion of heating/cooling centers, etc. that governments are meant to provide, and whether there are identifiable and unjustified inequities in the extent and quality of resources and infrastructure provided to different groups and locations throughout the state. Inequities might be attributed to shortcomings in government efficacy and intentions, rather than to limited resources and the historical aspects of differential development patterns.

#### Impact on Responders

Heat and freezing conditions may directly impact the health and effectiveness of responders, including the potential for dealing with impacts on overwhelmed or failed infrastructure. Special clothing and equipment (and maintenance) tends to become necessary under conditions of extreme cold. Frozen pipes may inhibit or limit responders’ access to water that is needed to fight fires, and extra activities and caution may be needed around wintry fire zones where water may have frozen and made footing treacherous for emergency workers (and others).

#### Impact on the Environment

Periods of extreme heat or cold can affect the environment in several ways. When the temperature rises, power consumption increases, as households and public buildings require more energy to run air conditioning. Agricultural areas also use more pumped water as irrigation is increased. More coal is burned to fulfill the rising demand and thus, more greenhouse gases and toxins are released into the air.

Long-term environmental damage includes greenhouse gas emissions that cause the earth’s temperature to rise even further, in what may be described as a “vicious circle.” The melting of glaciers in the arctic region will, along with the thermal expansion of ocean waters, increase the sea level, erode and flood coastal areas, and cause the extinction of many species.

#### Climate Change Considerations

Certain indicators of climate change in Michigan have already been observed. For example, in daily record temperature data, Michigan’s new heat records outnumbered new cold records by 3 to 1 during the 1990s, and by 6 to 1 during the 2000s. Extreme heat problems are expected to increase in the future, and the MSP/EMHSD is coordinating with other agencies to assess the likely impacts of warming trends.

#### ***Significant Heat Waves Affecting Michigan***

Following are brief synopses of some of the more significant heat waves that have affected Michigan in recent decades:

## **July 1936 – Michigan**

During the second week of July 1936, a terrible heat wave struck Michigan, and particularly Detroit, with temperatures exceeding 100 degrees for up to seven days in a row (this varied by location—for example, Detroit had 7, West Branch and Alpena had 6, and Traverse City had 5). The temperature peaked at 112 degrees in Mio, setting a state record that still stands today. The extreme heat was an “equal opportunity” killer, causing many healthy adults to succumb to the heat at work or in the streets. Also, because most people relied on iceboxes to keep their food fresh, many heat-related deaths and illnesses occurred when the ice melted, causing the food to spoil. Statewide, 570 people died from heat-related causes, including 364 in Detroit. Nationally, the heat wave caused 5,000 deaths. Notice that these casualties disproportionately affected the large city of Detroit, and that Michigan was over-represented in terms of its population (11.4% of the national deaths were in Michigan).

## **August-September 1953 – Michigan**

This summer included eleven days in a row with temperatures of 90 degrees or higher in Southeast Michigan, nine of which were 95 degrees or hotter, and also including two days that each hit 100 degrees.

## **July 1964 – Michigan**

A heat wave lasted for twelve days, with temperatures all exceeding 90 degrees in Southeast Michigan. The highest such temperature was 95 degrees.

## **Summer 1988 – Central and Eastern U.S.**

The 1988 drought/heat wave in the Central and Eastern U.S. also greatly impacted Michigan. Nationwide, the drought caused an estimated \$40 billion in damages from agricultural losses, disruption of river transportation, water supply shortages, wildfires, and related economic impacts. The heat wave that accompanied the drought conditions was particularly long in Michigan – 39 days with 90 degree or better heat – eclipsing the previous record of 36 days recorded in the “dust bowl” days of 1934. During that 39-day stretch, the temperature in Southeast Michigan topped the 100 degree mark on 5 occasions, including a peak of 104 degrees on June 25. Nationwide, the 1988 drought/heat wave caused an estimated 5,000 to 10,000 deaths. (Again, the range of estimates is due largely to varying interpretations of “heat-related” death.)

## **July 1995 – Central and Eastern U.S.**

During the period from July 11-27, 1995, the Central United States and many East Coast cities experienced a devastating heat wave. According to the National Oceanic and Atmospheric Administration, that heat wave caused 1,021 deaths - 465 of those occurring in the Chicago metropolitan area alone. Many of the deaths were low-income elderly persons living in residential units not equipped with air conditioning. Local utilities in Chicago were forced to impose controlled power outages because of excessive energy demands, and water suppliers reported very low levels of water in storage. In Milwaukee, Wisconsin, 85 heat-related deaths were reported during the July 11-27 period. Michigan experienced 28 heat-related fatalities in 1995, most of them occurring during the intense heat period in July. In addition to this tremendous human toll, the intense heat also caused the loss of tens of millions of cattle and poultry throughout the Midwest. This was the hottest summer on record for Southeast Michigan, in terms of having the highest average temperature in Detroit (74.5 degrees). The average August temperature was even higher, at 77.1 degrees, which also set a new record.

## **July 1999 – Midwest and East Coast**

The July 1999 heat wave that struck the Midwest and East Coast resulted in an estimated 256 heat-related deaths in 20 states (including one in Kent County in Michigan). Most of the deaths occurred in urban areas in the Midwest, where temperatures soared above 90 degrees for much of the month and humidity levels were oppressively high. Numerous persons with heat-related problems (ranging from dehydration to heat stroke) were treated at hospitals in Detroit and other cities across the state throughout the heat wave.

## **June-August 2001 – Midwest and Central Plains**

Extreme heat and humidity in the Midwest and Central Plains during parts of June, July and August sent heat stress index readings soaring well above 100 degrees Fahrenheit on many days. Communities across the region were forced to open “cooling centers” and take other steps in an attempt to avoid heat-related deaths among vulnerable segments of the population. Despite those efforts, heat-related deaths occurred in many areas – and unfortunately Michigan was no exception. In mid-June, three elderly residents of a Detroit-area nursing home died and five more were hospitalized due to heat-related stress. (Note: the deaths prompted a bill within the Michigan Legislature to require all nursing homes in Michigan to have air conditioning in resident rooms and common areas.) On August 1 and August 8, heat advisories were issued for many counties in the southern Lower Peninsula, with heat indices at 105 degrees for some jurisdictions on the former date, and 110 degrees for some jurisdictions on the latter date. The National Climatic Data Center reports one death and 200 “injured” during early August, from excessive heat.

## **June 2003 – Michigan**

Summer heat was part of the reason that Red Flag warnings were issued for two counties in the Upper Peninsula, warning of extreme wildfire risk. This was the same summer that saw a massive heat wave strike Europe and cause an estimated 21,000 deaths there. Paris, France recorded its highest temperatures since records had begun in 1873. Fortunately, Michigan did not experience those sorts of extreme problems.

## **Summer, 2006 – Southeastern Michigan**

The National Climatic Data Center reports that 315 “injuries” occurred as a result of heat in Michigan—75 occurring on May 29, and 240 in late July and early August, although most of the latter were mild cases involving dehydration, some heat exhaustion, and only 6 known cases of heat stroke. A 5 day period of temperatures at or above 90 degrees started on July 29 for Southeastern Michigan. The heat index averaged between 105 and 110 degrees, and various temperature records were tied. A large number of cooling centers were provided for residents in need, and preparedness was very good, perhaps because the earlier May 29 event had provided a milder warning event that alerted communities to the potential for heat problems. In that earlier case, on Memorial Day, temperatures went as high as the mid-90s (with a temperature of 98 reported at Midland), and outdoor parade events caused many to swoon and be treated for dehydration and heat exhaustion.

## **August 2007 – Michigan**

Red Flag warnings were issued for many Upper Peninsula counties, with extreme heat one of the main causes of the wildfire risk.

## **July 17, 2011 to July 22, 2011 – Southeast Michigan (Oakland and Wayne Counties)**

A mid-July heat wave helped cap off the warmest month on record at Detroit. Three direct deaths were reported due to the heat wave, as heat indices were above 100 degrees. A 37-year-old Highland Township (Oakland County) man died from several factors including an enlarged heart, obesity and hyperthermia. A 60-year-old man died in Wayne County from hyperthermia, as he was found in his car with the windows rolled up. A 57-year-old man was also found dead due to hyperthermia in his Redford Township (Wayne County) group home.

## **June 28 to July 7, 2012 – Southeast Michigan (Wayne, Oakland, Macomb, Washtenaw, Genesee, Saginaw)**

High temperatures climbed to around 100 degrees across much of southeast Michigan during the afternoon hours of June 28th, with heat indices climbing between 100 and 110 degrees. This led to an increase in heat-related hospitalizations. Temperatures slowly came down during the evening hours, with drier

air slowly filtering in. Although Friday June 29th ended up being hot, with high temperatures in the low to mid 90s, the dry air helped to keep heat indices short of 100 degrees. This was followed almost immediately by an extended heat wave that gripped southeast Michigan during the first week of July, with temperatures topping out around 100 degrees on multiple days. Detroit set a record high on July 4th, reaching 102 degrees. Heat indices peaked around 110 degrees on July 4th and July 6th. Although no known heat deaths were reported, over 700 heat-related emergency room visits were reported statewide. Southeast Michigan tallies included 39 heat injuries in Wayne County, 28 in Oakland County, 20 in Macomb County, 13 in Genesee County, 10 in Saginaw County, and 5 in Washtenaw County.

#### **July 14-19, 2013 – Southeast Michigan (Wayne, Oakland, Macomb, Washtenaw, Genesee, Saginaw)**

A six-day heat wave impacted Southeast Michigan from July 14 through 19, with high temperatures ranging from the upper 80s to mid-90s. Heat Indices were mostly in the 90s, but Detroit Metro area hospitals reported an increase of 173 heat related illnesses during this stretch—80 in Wayne County, 50 in Oakland County, 25 in Macomb County, and 6 in each of Washtenaw, Genesee, and Saginaw Counties.

**(NOTE: Oftentimes, heat waves exacerbate drought conditions, resulting in significant agricultural losses. For example, the summer heat of 1980 worsened the effects of a drought that caused over \$20 billion in agricultural damage. The drought / heat wave of the summer of 1999 caused a nationwide total of more than \$1 billion in damage—mainly to agricultural crops in the Eastern U.S. The “dust bowl” conditions of the 1930s are widely known and described in practically any U.S. history text. The most damaging drought / heat wave in the past few decades, however, was that of 1988, which affected the Central and Eastern United States. That event caused \$40 billion in damage, in addition to contributing to many deaths. See the Drought section for more information.)**

### **Significant Episodes of Extreme Cold Temperatures in Michigan**

#### **February 10 to 13, 1899 – Central and Western Lower Peninsula**

Record low temperatures occurred multiple days in a row. At Baldwin (Lake County), four days in a row had record low temperatures: -36, -49, -48, and -37 degrees Fahrenheit. Grand Rapids also noted four days in a row that set all-time records: -21, -21, -23, and -24 degrees. At Big Rapids (Mecosta County), three days in a row set records: -33 degrees, -36 degrees, and -34 degrees. Similarly, Hastings and Muskegon also set records for three days in a row: the former with -26, -31, and -24, and the latter with -30, -29, and -22 degrees.

#### **February 9, 1934 – Vanderbilt (Otsego County)**

The coldest recorded temperature in Michigan was at this location in the northern Lower Peninsula—at 51 degrees below zero!

#### **February 17, 1979 – Northern Michigan**

This was one of the coldest days that ever occurred in Michigan, in terms of the widespread presence (across 14 monitoring locations) of top-ten coldest temperatures. At Trout Lake (Chippewa County), the low was -43 degrees. At Harrisville (Alcona County), it was -20 degrees. To the west, at Traverse City, the temperature went down to -37. At Standish (Arenac County), the low was -24 degrees, and at Houghton Lake, it was -34.

#### **December 1993 to May 1994 – Upper Peninsula and Northern Lower Peninsula**

This was the deep freeze disaster that was federally declared (#1028) and can be read about in the corresponding disaster report that appears in Attachment F of the 2011 Michigan Hazard Mitigation Plan. Ten counties (Gogebic, Ontonagon, Houghton, Marquette, Delta, Schoolcraft, Chippewa, Mackinac, Cheboygan, and Charlevoix) were declared disaster areas when record low temperatures caused the freezing and breakage of more than 3,200 water and sewer lines. Service to 18,700 homes was disrupted. Public costs were estimated at more than \$12 million.

#### **December 9, 1995 – Detroit**

Winds averaged 20 to 25 mph and resulted in Wind Chill Temperatures of -30 to -35 degrees. Three deaths occurred from hypothermia in Detroit—two at street locations and one in a van. (The next morning, a man was also found frozen to death near his disabled vehicle 30 miles southeast of Ontonagon, where overnight low temperatures were -15 degrees and wind chill temperatures reached -60.)

#### **February 3 to 5, 1996 – Stephenson (Menominee County)**

There were three days in a row with record low temperatures in this area. The temperatures went down to -45, -44, and -41 at a spot 8 miles west-northwest of Stephenson, near the southern tip of the Upper Peninsula. On February 1, a few days before this event, a cold-related death was reported in Southeast Michigan, involving an elderly man who had wandered away from a nursing home in Detroit. That area of the state also experienced extreme cold, with Detroit's low on February 3 reaching -7 degrees. The temperature at Flint was zero degrees Fahrenheit, or below, for seven days in a row from January 31 to February 6.

#### **January 17 to 19, 1997 – Southeast Michigan**

The coldest weather of the winter occurred and resulted in two deaths from hypothermia—one in Bay City and the other (on January 12) in Warren. Low temperatures reached -6 at Detroit Metro Airport, and -9 at Flint's Bishop Airport.

#### **January 1999 – Saginaw County**

As a prelude, December 30, 1998 saw a damaging event at Saginaw Valley State University, when a sprinkler system pipe froze and burst, causing half a million dollars in damage at Brown Hall. Water was as deep as 3 to 4 inches in some offices by the time the break was discovered on New Year's Eve. Then, with January came more widespread events involving extreme cold. In Southeast Michigan, 3 persons died and 29 were confirmed as injured, as a cold blast crept around the sheltering Great Lakes and struck the southern Lower Peninsula. Temperatures went down to -13 at Ann Arbor and Tecumseh, and -10 in surrounding areas of Washtenaw, Lenawee, and Wayne Counties. The three deaths occurred in Oakland County on January 4. Confirmed injuries involved frostbite cases from a few hospitals in Oakland and Wayne Counties, and should be understood to represent only a small portion of the actual total from this event. On the early morning of January 11, a daily low temperature of -4 degrees was recorded, and on that day more than 120 water main breaks took place in the City of Detroit. A very large water main also ruptured in downtown Adrian, causing a shortage for 22,000 residents. Property damage was estimated at \$1.3 million.

#### **December 21 to 29, 2000 – Southeast Michigan (including the thumb area)**

In late December 2000 after heavy snow had ended, extreme cold temperatures invaded southeast Michigan, including portions of the thumb region. Temperatures never got out of single digits on the 22nd, with Detroit seeing a high of only 4 degrees, after a morning low of -3. Flint wasn't much better, recovering from a low of -5 to reach 8 degrees in the afternoon. Christmas morning had a morning low of -13 degrees at Flint, setting an all-time record for

the month of December. Three nights later, Flint would give the new record a run for its money, coming up just short with a low of -11 on the 28th. The arctic weather would take a toll on pipes. Both Ypsilanti High School and Chelsea High School had pipes burst over Christmas weekend, damaging classrooms. Several buildings on the University of Michigan campus in Ann Arbor had similar ruptures, including the School of Dentistry and Wolverine Tower. The cold also hampered shipping interests. Ice formation was extremely rapid on the Great Lakes and the connecting waterways. Several freighters got stuck in ice on both the Detroit River and Lake St Clair, blocking the shipping channel and bringing dozens of ships to a halt. Icebreaker assistance was needed to free the freighters. Ferry service on the St Clair River between Michigan and Canada was also interrupted due to ice jams. The end result was the 4th coldest December of all time in Detroit, and the 2nd coldest at both Flint and Saginaw. No other December on record comes close to this combination of heavy snow and brutal cold.

### **January 2003 – Lower Peninsula**

Temperatures averaged well below normal across the Great Lakes region for much of January. For a three week period, the temperature never rose above freezing. Temperatures fell below zero for several nights during this period. Frozen pipes and water main breaks occurred in many areas of Detroit and its suburbs. The cities of Flint and Saginaw also had several reports of water main breaks. Several area schools had to cancel classes due to frozen pipes. Many homeless shelters were filled to capacity and area hospitals reported dozens of cases of frostbite. Three deaths were also attributed to this cold spell.

### **February 3 to 6, 2007 – Southeast Michigan**

The worst cold wave event since the 1990s struck the region on February 3 and did not let up until February 6. Temperatures went as low as -7 at Saginaw and -5 at Flint, and winds of 15 to 25 mph included gusts of up to 35 mph. Wind Chill Temperatures ranged from -15 to -25 throughout almost the entire event, causing nearly every school district to cancel classes for one to two days. Hospitals reported numerous cold-related illnesses and frostbite cases. Area homeless shelters were filled to capacity. One death was attributed to the bad weather. Frozen pipes and water main breaks occurred throughout the area, and flooding occurred in cases where these involved sprinkler system pipes. Total damages were estimated at \$425,000. According to AAA, there were more than 20,000 vehicle service calls from Michigan due to the cold weather—more than had been seen for nearly 10 years.

### **February 9-11, 2008 – Upper Peninsula**

Temperatures of 5 to 15 below zero combined with around 35 mph wind gusts drove bitterly cold wind chill values down to 25 to 40 below zero over much of Upper Michigan from the night of the 9th into the morning of the 11th. The powerful Arctic cold front pushed through the Upper Great Lakes on the afternoon and evening of the 9th and also produced blizzard conditions with lake effect snow and blowing snow over portions of Upper Michigan into the 10th. Many schools were either canceled or delayed on the 11th. AAA Michigan reportedly responded to numerous motorists' calls of dead batteries or fuel line freezes during the extreme cold.

### **January 14-18, 2009 – Southeastern Michigan**

An arctic air mass became firmly established over the Great Lakes region on January 14th and persisted through the 18<sup>th</sup>, producing the winter season's coldest temperatures. Temperatures fell below zero all four days, with wind chill values in the 5 to 30 below range during the majority of the time. Detroit's low temperatures for January 14-18th were as follows: -3, -3, -15, -11. Wind chill values also plummeted to 20 to 40 below zero from late evening on the 13th through the morning of the 16<sup>th</sup> throughout much of the Upper Peninsula.

### **April 27, 2012 – Lower Michigan – Late Freeze**

A killing freeze caused extreme damage to agriculture in the Lower Peninsula, particularly in the fruit belt of its northwest. Traverse City saw low temperatures of 25 degrees on April 27th, 31 degrees on the 28th, and 26 degrees on the 29th. Although these values were not greatly colder than normal lows, because of a stretch of unprecedented warmth in mid-March which had included five consecutive 80-degree days (17th-21st) that had caused fruit trees to bud out far ahead of schedule, these trees were left vulnerable when more normal April temperatures returned. The tart cherry crop was a total loss, while other orchard fruits such as sweet cherries, apples, pears, and peaches saw losses in excess of 90% of the expected crop. Total losses exceeded \$100M.

### **Early 2014 – Statewide**

Several times during the 2013-2014 winter season, very low temperatures were felt across the state, for periods of time that placed many persons at risk. This sometimes coincided with ice storms, power failures, propane shortages, and transportation blockages which caused the effects of the extreme cold temperatures to be more pronounced. The media made the term "polar vortex" popular during these extreme temperature events. More information about these events will be available in a future edition of this document, since they are still ongoing at the time of writing.

## ***Programs and Initiatives***

### **Extreme Summer Heat**

*Excessive Heat Events Guide Book* – A product of the Environmental Protection Agency, in conjunction with FEMA, NOAA, and the Center for Disease Control and Prevention, this booklet can be obtained online at <http://www.epa.gov/heatisland/about/heatguidebook.html>. It provides an overview of heat impacts, sources of risk, notification and response programs, and recommendations.

*Summer Heat Contingency Planning* – In the aftermath of the extreme summer heat events of 1980 and the early 1990s, many major cities began to develop contingency plans for addressing heat-related hazards. The major elements of these plans include: 1) enhanced weather monitoring to better predict periods of extreme heat; 2) increased outreach to the elderly and other vulnerable individuals; 3) establishment of "cooling centers" for those most affected by the heat; and 4) enhanced public information campaigns to inform people of the perils of extreme summer heat and the resources available to them. In Michigan, cities such as Detroit and Lansing, among others, now address extreme summer heat contingencies in their emergency planning efforts.

*Low Income Home Energy Assistance Program / State Emergency Relief Program* – The LIHEAP is a federally-funded program to help eligible low income households meet their home heating or cooling needs. The money is used to help pay high utility bills or buy fans or air conditioners for persons considered at risk from extreme summer heat and it helps to pay for heat and weatherization during extreme winter cold. In 2003, about 4.6 million Americans received over \$1.5 billion in assistance under the LIHEAP. Michigan received \$40.8 million of that money to help aid low income citizens with heating expenses. In Michigan, the state Department of Human Services determines which families are eligible. In addition, the State Emergency Relief (SER) Program can also be used to alleviate the dangers of extreme heat and cold for Michigan families by providing financial assistance for home heating, electric and water bills.

#### Extreme Winter Cold

Since illness and death from hypothermia are not only seen in association with prolonged periods of cold temperatures, efforts to prevent hypothermia must be ongoing throughout periods of cooler weather. Because elderly persons are particularly vulnerable to hypothermia, prevention efforts must be primarily directed to them. Family, friends, neighbors, and local governmental and voluntary agencies can help ensure that all dwellings in which elderly persons reside are properly heated. This may require that a regular outreach program be established for this purpose. Local communities should also have adequate housing codes that require dwellings to have furnaces capable of maintaining sufficient room temperature for the winter conditions that will normally be expected. Governmental authorities, voluntary agencies and utilities can also assist those elderly persons that cannot pay all or part of their heating bills by providing financial assistance and/or making special arrangements for payment. Finally, governmental and voluntary agencies should, in conjunction with local media, continue to address the dangers associated with cold temperatures through regular public information and awareness campaigns. The combination of all these activities certainly will not prevent all cold temperature-related injuries and deaths, but it will go a long way toward preventing a large share.

#### ***Mitigation Alternatives for the Extreme Temperatures Hazard***

- Organizing outreach to vulnerable populations during periods of extreme temperatures, including establishing and building awareness of accessible heating and/or cooling centers in the community, and other public information campaigns about this hazard.
- Increased coverage and use of NOAA Weather Radio.

#### ***Tie-in with Local Hazard Mitigation Planning***

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of extreme temperatures), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, the information immediately following provides advice regarding the extreme temperatures hazard to offer guidance to local planners, officials, and emergency managers. It has been adapted from the February 2003 “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207). For the second type of State-local planning coordination, a section follows that summarizes extreme temperature information as it has been reported in local hazard mitigation plans. For a brief summary of temperature-related information from that section of this plan, it will here be noted that extreme temperatures were identified as one of the most significant hazards in local hazard mitigation plans for the following counties: Alger, Barry, Berrien, Cass, Gogebic, Leelanau, Mason, Menominee, Monroe, Montmorency, Muskegon, Oceana, Otsego, Wayne (14 counties).

# FOG

*Fog: Condensed water vapor in cloudlike masses lying close to the ground and limiting visibility.*

## **Hazard Description**

Fog forms near the ground when water vapor condenses into tiny liquid water droplets that remain suspended in the air. Many different processes can lead to the formation of fog, but the main factor is saturated air. Two ways that air can become saturated are by cooling it to its dew point temperature or by evaporating moisture into it to increase its water vapor content. Although most fog, by itself, is not a hazard because it does not actually apply destructive forces, the interaction between humans and fog can be a dangerous situation, sometimes resulting in disastrous consequences. It must be noted, however, that **freezing fog** (a hazard for which the National Weather Service does issue special statements) can cause direct harm by causing slickness on roadways and thus leading to serious transportation accidents (examples are provided later in this chapter).

## **Haze and Smog**

Haze occurs when dust, smoke and other pollutant particles obscure the normal clarity of the sky. It occurs when dust and smoke particles accumulate in relatively dry air. When weather conditions block the dispersal of smoke and other pollutants, they concentrate and form a usually low-hanging shroud that impairs visibility and may become a respiratory health threat, as well as make safe driving more difficult. Dense haze caused by industrial pollution is also known as smog. This hazard may cause public health problems, so it is mentioned in this subsection but is not given particular emphasis since this plan has more of an emergency management focus. It is noted here as an area of potential overlap and future coordination with other agencies. The Michigan Department of Community Health and the Michigan Department of Natural Resources may do more with this issue in the future, if the effects become severe enough. Since it may be possible that climate change issues cause this to be a more frequent and ongoing concern in Michigan, it is mentioned here. In general, however, air quality has generally improved since the effects of the Clean Air Act, other legislation, regulatory measures, and shifts away from heavy industry in Michigan's economy.

Smoke-producing hazards may have an effect that seems visually comparable to fog. For example, wildfires, hazardous materials incidents, structural fires, major transportation accidents, or industrial accidents may produce clouds of smoke that can obscure visibility and increase the risk of transportation accidents.

## ***Hazard Analysis***

In considering severe and high-impact meteorological events, attention can easily become focused on the more dramatic storms. Tornadoes and hurricanes for example, are readily recognized by the general public and the meteorological community alike for their devastating consequences. Fog, on the other hand, does not lend itself as readily to this categorization. Yet, both in cost and casualties, fog has consistently impacted society, and in particular the transportation sector - sometimes with deadly consequences. Fog has played a contributing role in several multi-vehicle accidents over the past several years. While statistics suggest that highway accidents and fatalities, in general, have fallen, that trend is not evident with respect to accidents and fatalities caused by fog.

Fog can be very dangerous because it reduces visibility. Although some forms of transport can penetrate fog using radar, road vehicles have to travel slowly and use more lights. Localized fog is especially dangerous, as drivers can be caught by surprise. Fog is particularly hazardous at airports, where some attempts have been made to develop methods (such as using heating or spraying salt particles) to aid fog dispersal. These methods have seen some success at temperatures below freezing.

One major fog event is estimated to occur in Michigan approximately every two years. Property damage can be significant for vehicles, although real property and structures are usually unaffected. Fog has not yet been identified as one of the most significant hazards in any of Michigan's local hazard mitigation plans.

**Fog History for Michigan Counties – arranged by region** – Jan. 1996 to Oct. 2013  
(The Lower Peninsula regions are ordered by “tiers” from south to north, west to east)  
Please refer to the Michigan Profile Map section for an explanation of regional divisions

<b>COUNTY or area</b>	<b>Fog Events</b>	<b>Days with Fog</b>	<b>Injuries</b>	<b>Deaths</b>
Washtenaw	2	2		
Wayne	2	2		
.Livingston	1	1		
Oakland	1	1		
Macomb	1	1		
<b>5 Co Metro region</b>	<b>1.4 avg.</b>	<b>1.4 avg.</b>		
Berrien				
Cass				
St. Joseph				
Branch				
Hillsdale				
Lenawee				
Monroe	1	1		
.Van Buren	1	1		
Kalamazoo	1	1		
Calhoun	1	1		
Jackson	1	1		
.Allegan	1	1		
Barry	1	1		
Eaton	1	1		
Ingham	1	1		
.Ottawa	1	1		
Kent	1	1		
Ionia	1	1		
Clinton	1	1		
Shiawassee	1	1		
Genesee				
Lapeer	2	2	1	1
St. Clair	1	1		
.Muskegon				
Montcalm				
Gratiot				
Saginaw	1	1		
Tuscola				
Sanilac	1	1		
.Mecosta				
Isabella				
Midland	1	1		
Bay	1	1		
Huron				
<b>34 Co S Lower Pen</b>	<b>0.6 avg.</b>	<b>0.6 avg.</b>	<b>1</b>	<b>1</b>

Continued on next page...

**Part 2 of Michigan County Fog Hazard History table**

.Oceana				
Newaygo				
.Mason				
Lake				
Osceola				
Clare				
Gladwin				
Arenac				
.Manistee	1	1		
Wexford				
Missaukee				
Roscommon				
Ogemaw				
Iosco				
.Benzie				
Grand Traverse				
Kalkaska				
Crawford				
Oscoda				
Alcona				
.Leelanau				
Antrim				
Otsego				
Montmorency				
Alpena				
.Charlevoix				
Emmet				
Cheboygan				
Presque Isle				
<b>29 Co N</b>	<b>0.03 avg.</b>	<b>0.03 avg.</b>		
<b>Lower Pn</b>				
Gogebic	3	3		
Iron	2	2		
Ontonagon	3	3		
Houghton				
Keweenaw	3	3		
Baraga	4	4		
.Marquette	4	4		
Dickinson	3	3		
Menominee	3	3		
Delta	4	4		
Schoolcraft	4	4		
Alger	4	4		
.Luce	4	4		
Mackinac				
Chippewa				
<b>15 Co Upp.Pen</b>	<b>2.7 avg.</b>	<b>2.7 avg.</b>		
<b>MICHIGAN</b>	<b>82</b>	<b>19</b>	<b>1</b>	<b>1</b>
<b>TOTAL</b>				

### Impact on the Public

The primary risks from fog involve the dangers of traveling under conditions of limited visibility. Although some modes of transportation, such as aircraft, are well-regulated, other modes, including simple pedestrian travel, may involve risks that have not been properly accounted for by those who are focused merely on reaching their destination as quickly as possible. The most substantial impacts have recently involved drivers whose bad habits (primarily that of not maintaining safe speeds and following distances) proved to be simply unsustainable under conditions of reduced visibility, resulting in severe crashes and subsequent roadway obstruction. In some circumstances, these conditions of reduced visibility can arise very quickly, although careless drivers, in their desire for fast travel conditions, may erroneously try to ignore the risks from reduced visibilities, in the hope that the condition will suddenly correct itself before any harm is caused.

### Impact on Public Confidence in State Governance

This hazard is not expected to cause serious impacts upon public perception of the State's governance, so long as the cautionary messages issued by the National Weather Service and other agencies are received and understood. One reason for the estimated lack of impact on public confidence is that (1) the hazard is typically a localized one not presumed to be dealt with at a State level, (2) public announcements tend to be made when visibility gets too low, and (3) the airline industry operates under regulations (and also uses special equipment) to alleviate the risks from fog. The most serious incidents in Michigan, in which extensive chain-reaction car crashes have occurred on interstate highways, could arguably be connected with too lax of enforcement of fundamental traffic laws (primarily the infractions of following too closely and speeding), but a large proportion of the public, which persists in such unsafe and often unconscious driving habits, seems unlikely to perceive or understand any such hypothetical connection between these conditions.

### Impact on Responders

In certain circumstances that require an emergency response, heavy fog may cause impediments and risks that would not normally be present. This is especially true in cases involving high-speed mechanized transportation that requires good visibility to maintain adequate and safe control and maneuvering ability, and for situations that involve search and rescue operations, for which visibility may be very important in locating and assisting victims. Response activities involving aircraft, for example, may be impaired or harmfully delayed by fog.

### Impact on the Environment

Fog on its own does not directly impact the environment. However, fog may reduce visibility and can create dangerous traveling conditions. Transportation accidents involving a chemical release may cause great harm to the environment by releasing toxins into the soil, groundwater or air. (Please refer to the chapter on hazardous materials, in the Technological-Industrial Hazards section of this plan.)

## **Recent Significant Fog-Related Incidents in Michigan**

### **January 11 to 13, 1995 – Michigan's Lower Peninsula**

In January 1995, dense fog blanketed much of Lower Michigan from the evening of the 11th through the morning on the 13th. The fog caused numerous traffic accidents, which resulted in four fatalities. School openings were delayed in parts of southwest Michigan as visibilities dropped to near zero. Low visibilities caused most of the flights at Detroit's metro airport to be cancelled, delayed or diverted on the 12th. About seventy-five flights were also delayed or cancelled at Kent County International Airport in Grand Rapids.

### **October 25- 26, 2000 – Southeastern Metro Areas**

On the morning of October 25, dense fog dropped visibilities to only about an eighth of a mile at the MBS International Airport (Saginaw County), causing most of the morning flights to be cancelled. In addition, several area school districts delayed the start of classes that morning. On the following morning, October 26, dense fog had a similar effect upon Metropolitan Detroit, causing dozens of flights to be delayed at the Detroit Metro Airport, and slowing the traffic of morning commuters on the area's roads and highways.

### **October 11 to 12, 2002 – Lapeer County**

At certain times, dense fog reduced visibility to near zero in many locations. A 17 year old teenager was killed in Goodland Township when his pickup truck collided with a dump truck that was hauling a trailer. In a separate incident, a slightly older 19 year old driver failed to stop at a sign, and struck a school bus, resulting in one injury.

### **January 12, 2005 – Ingham County**

Up to 200 cars collided on an expressway, in a chain of crashes blamed on heavy fog in Ingham County on January 12, 2005. Two people were killed and thirty-seven others were taken to local hospitals. It was the worst crash in mid-Michigan in recent years and shut down both lanes of Interstate 96 between Okemos and Webberville for several hours. The dense fog cut visibility to around ten feet during rush hour.

### **September 13, 2006 – Shiawassee County**

Dense fog was reported to have caused three semi-trucks to roll over, a car crash and a separate car fire on I-69. As a result, that expressway had to be shut down in both directions between M-71 and the Grand River exit (a distance of about 4.5 miles), until the accidents could be cleared. A total of seven persons were injured in these crashes.

#### **November 24, 2006 – Monroe County**

In November, 2006 freezing fog caused zero visibility and created extremely dangerous driving conditions that led to numerous vehicle collisions. A semi-truck rollover accident resulted in the death of one man. Portions of I-275 were shut down for several hours due to the accident. Ten injuries were (indirectly) associated with the hazardous fog on this day.

#### **January 12, 2009 – Southern Lower Peninsula**

The National Weather Service issued an advisory (for 17 counties) about freezing fog that would not only reduce visibility, as normal fog does, but would also freeze upon some roadways and “aggravate already slick conditions.”

#### **May 22, 2010 – Manistee County**

Dense fog inhibited visibility in the area. At the entrance to Manistee Harbor, a fishing boat struck a pier, took on water, and submerged. Seven persons were rescued from the water, but there were two injuries and a death that still resulted (plus four persons who were less seriously harmed and merely required medical treatment on-site).

## **Programs and Initiatives**

### National Weather Service Detection Systems

The National Weather Service has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property. Although the NWS Doppler Radar does not directly detect fog, the point of greatest importance is that the lead-time and specificity of warnings for severe weather have improved significantly, and a dense fog advisory is reported when widespread or localized fog reduces visibility to a quarter mile or less.

Weather satellites are useful tools in monitoring and detecting the formation of low stratus clouds and fog. Satellite images are obtained using two Geostational Operational Environmental Satellites (GOES) and NOAA polar satellites. Remote sensing with GOES and NOAA polar satellites allows for the continuous monitoring of weather across the Earth. Channels on these satellites allow the use of infrared images at night. During the daytime hours, visible satellite data can be used to locate areas of stratus clouds and fog, and water vapor imagery has also been found to be helpful.

### Automated Surface Observation System (ASOS)

In the 1980s the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD) were faced with the need to find cost-effective ways to provide pilots with critical weather information. With NWS in the lead role, these federal agencies began development of automated sensors that were intended to eventually replace human weather observers. This automated sensor development culminated in the fielding of two systems: The Automated Weather Observation System (AWOS) and the Automated Surface Observation System (ASOS). AWOS and ASOS sensors provide continuous measurements of ceiling, visibility, temperature, dew point, wind speed and direction, and precipitation. All ASOS sites and some AWOS sites also have lightning detection and reporting, courtesy of the Automated Lightning Detection and Reporting System (ALDARS). Beginning in 1992, ASOS sites started to replace manual surface aviation observations. There are currently 882 federally sponsored ASOS sites around the country, and 24 of them are in Michigan. Fog is considered to be an obstruction to visibility when the temperature and dew points are within 5°F of each other. When the difference is more than five degrees, haze is reported.

### Automated Weather Observing System (AWOS)

The Automated Weather Observing System (AWOS) is a suite of sensors, which measure, collect and disseminate weather data to help meteorologists, pilots and flight dispatchers prepare and monitor weather forecasts, plan flight routes, and provide necessary information for correct takeoffs and landings. An AWOS provides minute-to-minute updates that are usually provided to pilots by a VHF radio on a frequency between 118 and 136 MHz. An AWOS is categorized as either federal or non-federal. A federal AWOS was purchased and is currently maintained by the FAA. A non-federal AWOS is purchased and maintained by state, local, and private organizations. The sensors measure weather parameters such as wind speed and direction, temperature and dew point, visibility, cloud heights and types, precipitation, and barometric pressure. The AWOS does not predict weather, but may send current information to weather offices where forecasts are produced using this information along with computer model outputs, satellite photos and radar images. There are currently twenty-eight Automated Weather Observing Systems in Michigan.

### Information Broadcast by an AWOS III

Airport Identifier	Zulu Time
Sky Conditions	Visibility
Wind Speed	Wind Direction
Temperature	Dew Point
Altimeter Setting	Remarks
Density Altitude	Wind Gusts

### Advanced Weather Interactive Processing System (AWIPS)

The Advanced Interactive Processing System (AWIPS) is an interactive computer software system with a full suite of satellite imagery used to analyze meteorological and hydrological data. This system is used by the National Weather Service (NWS) to predict weather patterns, prepare forecasts, and issue weather-related warnings. AWIPS has been the foundation of the NWS operations for the past decade but was planned for update to AWIPS II in 2011. The newly updated software, which is being developed by the NWS and a private entity, will allow data to be processed more efficiently, resulting in greater accuracy of weather forecasting.

### Lighthouses

Lighthouses are key parts of the infrastructure for water transportation, especially when dealing with the dangerous element of fog. Michigan has more lighthouses than any other U.S. state, by quite a large margin. In addition to traditional lighthouses, Michigan has many minor aids to navigation, in the form of cylindrical steel towers with navigation beacons at the top. These are known as D9 towers (named after the ninth Coast Guard district). Some of the D9 towers are regarded locally as being lighthouses, but most are not. Below is a list of lighthouses in Michigan that are still operational.

### Operational Lighthouses in Michigan

Name	Lake	Name	Lake
Detroit River Light	Erie	Minneapolis Shoal Light	Michigan
Cheboygan River Range Front Light	Huron	Muskegon South Breakwater Lights	Michigan
Detour Reef Light	Huron	North Manitou Shoal Light	Michigan
Fort Gratiot Light	Huron	Escanaba Light	Michigan
Forty Mile Point Light	Huron	Fourteen Foot Shoal Light	Michigan
Harbor Beach Light	Huron	Point Betsie Light	Michigan
Martin Reef Light	Huron	Poverty Island Light	Michigan
Middle Island Light	Huron	Frankfort North Breakwater Light	Michigan
Poe Reef Light	Huron	Grand Haven South Pier Head Lights	Michigan
Pointe Aux Barques Light	Huron	Grays Reef Light	Michigan
Port Austin Reef Light	Huron	Seul Choix Pointe Light	Michigan
Port Sanilac Light	Huron	Skillagalee Light	Michigan
Presque Isle Lights	Huron	South Haven South Pierhead Light	Michigan
Round Island Passage Light	Huron	St. Helena Island Light	Michigan
Sturgeon Pointe Light	Huron	St. James Light	Michigan
Tawas Pointe Light	Huron	White Shoal Light	Michigan
Thunder Bay Island Light	Huron	Lake St. Clair Light	St. Clair
Alpean Light	Huron	St. Clair Flats South Channel Range	St. Clair
Spectacle Reef Light	Huron	Au Sable Light	Superior
Round Island Light	Mackinac Straits	Big Bay Point Light	Superior
Little Rapids Cut Range Light	St. Mary's River	Passage Island Light	Superior
Big Sauble Point Light	Michigan	Rock of Ages Light	Superior
Charlevoix Light	Michigan	Gull Rock Light	Superior
Charlevoix South Pier Light	Michigan	Huron Island Light	Superior
Holland Harbor (South Pier Head Light)	Michigan	Isle Royale Light	Superior
Lansing Shoal Light	Michigan	Keweenaw Waterway Entrance Light	Superior
Little Point Sable Light	Michigan	Manitou Island Light	Superior
Ludington North Breakwater Light	Michigan	Marquette Harbor Light	Superior
Manistee Light	Michigan	Mendota Light	Superior
Manistique (East Breakwater) Light	Michigan	Munising Range Lights	Superior
Menominee Light	Michigan	Eagle Harbor Light	Superior
		Whitefish Pointe Light	Superior

#### Michigan Lighthouse Assistance Program Grants

The Michigan Lighthouse Assistance Program was established by the Michigan legislature in 1999 to assist local groups in preserving and protecting lighthouses. The program arose from the efforts of the Michigan Lighthouse Project, out of concern for the disposal of some 70 lighthouses by the U.S. Coast Guard. Two-thirds of Michigan's lighthouses currently under federal ownership are scheduled for disposal within the next decade.

#### ***Mitigation Alternatives for the Fog Hazard***

- Increased coverage and use of NOAA Weather Radio.
- De-icing measures (for freezing fog), as would be used for other ice-related hazards.